

G7 Broadband Dynamics

How Policy Affects Broadband Value in Powerhouse Nations

Richard Bennett

Visiting Fellow

American Enterprise Institute

Washington, DC

Preliminary Draft 0.3

September 15, 2014

Executive Summary

As we become more dependent on information technologies, questions about how to build, sell, regulate, and upgrade broadband networks become ever more crucial. Broadband networks are key enablers of information technologies as well as products of them, so their status tells us a great deal about the extent to which technology permeates the modern society.

Policy experiments over the past decade provide insight into the effects that regulatory policies have on the vibrancy of these networks and the richness of the applications they enable. Policy isn't the whole story, however: nations differ with respect to geographic, historical, and cultural factors that strongly influence the motivation to invest in technology and the ability reap its benefits.

Isolating the effects of policy from these other factors is easiest when we compare broadband diffusion, quality, utilization and cost in nations that are similar in size, economic development, education, and population distribution; hence this study examines broadband in the G7 nations.

The Internet Heat Map developed by Shodan also tells us that the G7 is where the action is on the global Internet.

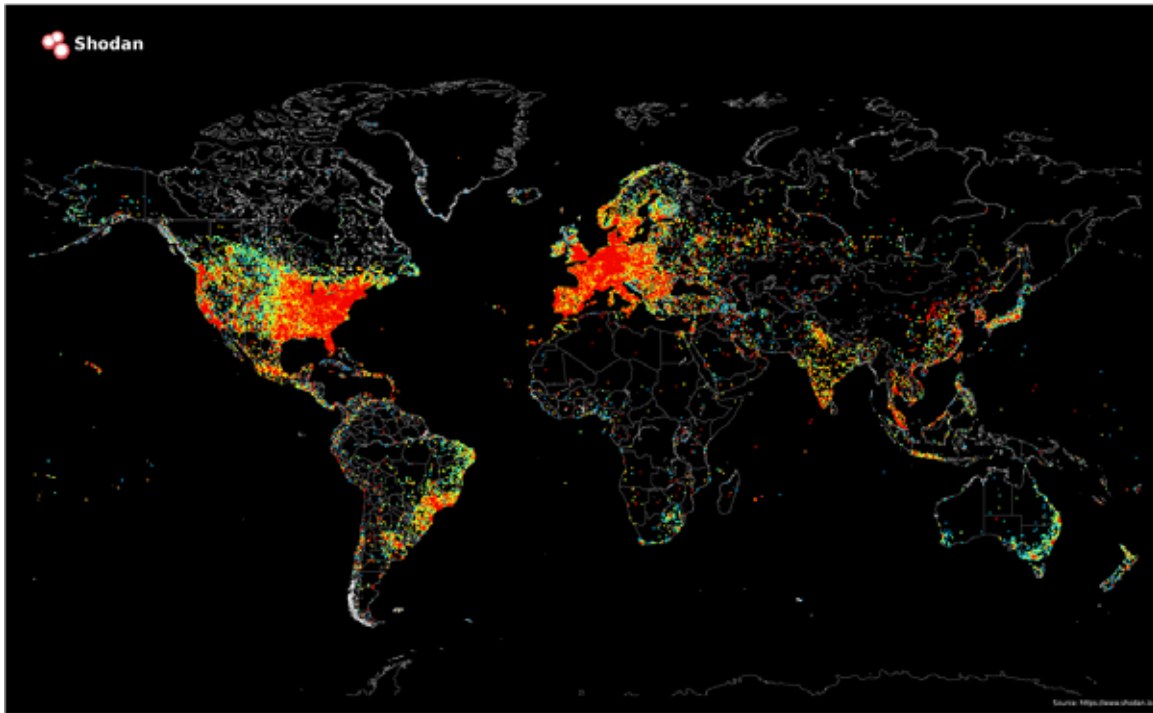


Figure 1: Internet Heat Map. Source: Shodan (<https://www.shodan.io>)

Three Broadband Policy Models

Three regulatory models emerge from this analysis:

- The “Pioneer Model” of dynamic, facilities-based competition in the U. S. and Canada;
- The “Contingent Model” of semi-deregulated advanced networks and price controlled legacy networks in Japan, U. K. and Germany;
- The “Utility Model” of low priced, poor quality, subsidy-dependent service over stagnant broadband infrastructure in France and Italy.

Even within the G7, there are sharp differences in the starting points for the broadband race. Some countries had extensive cable TV networks before broadband was invented, others had cable only in cities, and yet others had no more than a smattering. The extent of cable coverage influenced the development of regulatory models that in turn either advanced or suppressed the deployment of broadband networks.

In some countries, broadband was addressed as utility networks had been in the past, as a one-time build that would essentially have a permanent life span, while others adopted policies that encouraged the displacement of first generation broadband networks by better ones in the second, third, and fourth generations. The recognition of the dynamic nature of technology is challenging to historical norms in public infrastructure policy. The Pioneer Model best accommodates dynamism, but the Contingent Model can do a credible job when regulators are highly skillful, as they are in the U. K.; it is much less effective in Germany and only moderately effective in Japan.

Three Phases of Broadband Development

Broadband networks appear to develop across three distinct phases:

- The Basic Broadband stage in which existing wired telephone, cellular telephone, and cable TV networks are coupled with broadband electronics to provide a basic level of connectivity 10 to 100 times greater than the legacy system.
- An Advanced Broadband stage in which the wire and radio infrastructure is reconfigured to work better for broadband and connectivity improves another 10 to 100 times.
- A Pervasive Broadband stage in which most end-user connections are wireless at speeds produced only by wired systems in earlier stages and a pervasive fiber optic backbone extends so thoroughly that wireless can be provided over short hops that are not technically challenging.

It wasn't possible to jump directly from the pre-broadband status quo to the Pervasive stage because key technologies did not exist; indeed, the technology that will carry us into the pervasive stage is still not complete. Hence, broadband poses a massive challenge to policy makers simply by its dynamism.

Universal Service

Universal coverage for Basic broadband is a solved problem in the G7 because the combination of DSL, cable, 3G and 4G mobile, fiber, and satellite reaches even the most remote parts of the G7. The pressing issues today concern the initial deployment of advanced and pervasive technologies and their diffusion from healthy urban markets to more challenging rural ones.

The use of subsidies is a live issue in rural diffusion: shall subsidies be used to stimulate R & D, as they are in the form of National Science Foundation grants to U. S. universities? Or shall they fund initial deployment, as they are in the Contingent nations? Shall they be used to improve rural coverage, as they do in most nations? Or shall subsidies be used to create competitors, as they often are in Utility Model nations? Shall we simply use subsidies to create the illusion of low consumer prices by shifting costs? Free.fr, the low price leader in French broadband, is a regulatory creation that depends on inflated telephone termination fees for its survival, for instance, and many self-styled public interest groups place an inordinate emphasis on low prices at the expense of technical progress.

Measuring Performance

Policy analysts often measure broadband progress by metrics that tell very little about where we are on the expected trajectory, such as "penetration" (subscriber count) and dollars per bit per second of capacity. It's better to examine the deployment of advanced technology networks, the actual performance networks exhibit while running real world applications, and the volume of data they carry. When we do this, we see the most advanced wired and mobile networks are those in Japan, the U. S., and Canada; networks in the U. S. and Canada carry the heaviest data loads; the heaviest mobile loads are carried in Japan and the U. S.; and smartphone adoption is most pervasive in the U. S. and U. K.

The emphasis on raw network capacity has caused policy makers to overlook the fact that the personal experience of the World Wide Web is shaped more by the performance of servers, personal devices, and browsers than by network capacity; the FCC's data shows that 60 percent of the load time of web pages is determined by non-

network factors as long as consumers are connected at 20 Mbps or better, although the agency does not remark on the role of non-network factors.

Measuring Value

Value calculations cannot be made simply on the basis of consumer price for a given unit of capacity because provider costs are determined by distance and volume to a greater degree than capacity. The rural populations of the U. S. and Canada are widely dispersed, at 33 and 14 persons per square kilometer of arable land respectively, vs. 994 and 268 for Japan and Italy. As a consequence, each Internet Exchange in Canada serves some 222,000 sq. km. of populated area compared to 14,000 in Japan; this raises costs of Internet access in Canada substantially.

Despite its extensive geography, Canada's mobile networks provide value similar (in terms of the bandwidth to profit ratio) to those in Japan. U. K. mobile networks provide excellent mobile value, but they should given that they serve the second smallest rural population (in proportion to national population) in the G7 and they purchase backhaul from a cash flow negative monopolist.

High Consumer Value

Canada achieves high consumer value despite having the highest broadband bills in the G7 because of the territory it contains, the speeds of Canada's networks, and their heavy usage. Medium speed wired broadband is nearly as prevalent in Canada as it is in Japan, a nation awash in fiber optic networks. The U. S. outperforms Canada in terms of raw wired network capacity, but we run neck-and-neck with U. K. and behind Japan. Oddly, the nations with the most pervasive LTE mobile networks exhibit some of the lowest speeds; this is partially because a widespread network is required to carry greater load than one in its early phase of adoption; it is also partially because LTE is sold as a premium service in Europe but is included in standard smartphone plans in the U. S. The U. S. and Canada greatly outperform Europe in delivering the broadband performance levels carriers advertise; over 100 percent vs. 80 percent.

Some advocates complain that U. S. broadband networks earn excessive profits, but this claim is unsupportable. For mobile networks, the bandwidth/profit ratio was lowest in U. K. and Japan and next lowest in the U. S. and Canada in 2013, despite the challenges that prairie nations face compared to island nations. The U. S. has the best ratio of bandwidth to revenue for mobile, followed closely by Japan, Canada, and U. K.

For wired networks, only approximate conclusions can be drawn due to imprecise data, but the indications suggest that the leading nations in bandwidth/profit may be Japan, U. K., and the U. S. In terms of the bandwidth/investment ratio, France, Japan, and the U. S. are the leaders.

Are Broadband Firms Excessively Profitable?

Compared to other firms in the Internet space, carriers are substantially less profitable than content creators and edge service providers, regardless of whether we measure free cash flow, total return, or return on invested capital. ROIC calculations indicate that broadband carriers are subject to greater competitive pressure than Internet giants Google, eBay, Netflix, and Facebook. Given this fact, calls for price-controlled interconnection to benefit edge providers are difficult to support.

Canada and the U. S. invest more per capita and per household than all others in the G7; this is a likely consequence of geography, policy, and culture.

The Broadband Scorecard

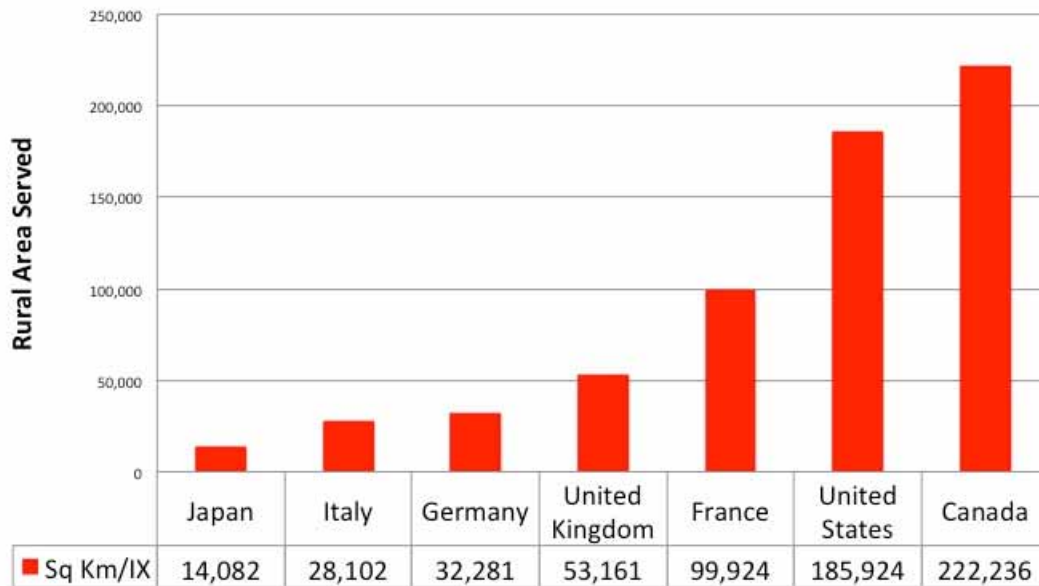
Summing up all the factors and placing them in a scorecard makes the analysis easy to comprehend. In terms of 11 criteria comprising geography, deployment, adoption, usage, value, and investment, G7 nations following the Pioneer Model do best, Utility Model nations do worst, and Contingent Model states are in the middle.

	Rur	NGA	LTE	Smart phone	>10M	Mob >4M	Use	Mob use	BW/ Pr	MBW/ Pr	Inv	AVG
United States	1	2	1	1	2	2	1	2	1	2	1	1.45
Japan	3	1	2	2	1	1	2	1	1	1	2	1.55
Canada	1	2	1	2	2	1	1	2	2	2	1	1.55
United Kingdom	2	2	3	1	2	1	2	2	1	1	3	1.82
Germany	2	2	2	2	3	3	3	3	2	2	3	2.45
France	2	3	3	2	3	1	3	3	2	3	2	2.45
Italy	3	3	3	3	3	1	3	3	3	3	2	2.73

Figure 2: G7 Broadband Scorecard Standings

The first factor is Rural Population Diffusion, an obstacle that has to be overcome. The following graph is a rough calculation of the square kilometers of inhabited land area served by each Internet Exchange. This tells us how many kilometers of cable must be installed to connect people to the Internet in a relative sense. The U. S. and Canada have the hardest problem to solve.

G7 Rural Area Per Internet Exchange

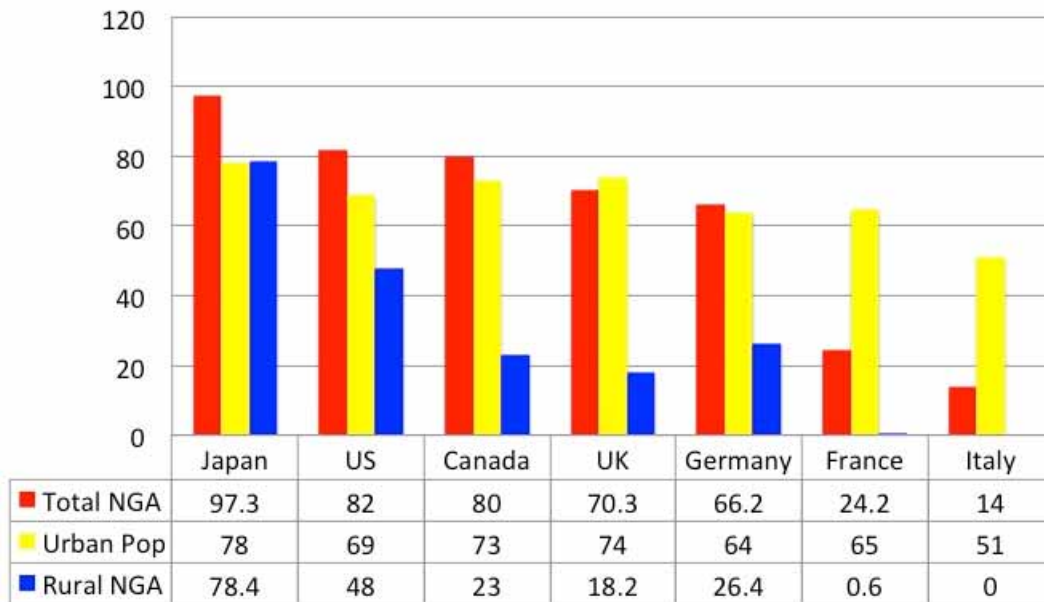


Source: World Bank, PeeringDB

Figure 3: G7 Rural Area Per Internet Exchange

The next factor is the diffusion of advanced broadband networks in each country, or “Next Generation Access” in policy-speak. Networks that can provide 25 Mbps of capacity without significant congestion generally qualify as NGA. The most important dimension in this graph is “Total NGA”, the red bar. Japan does exceptionally well here, and the U. S. and Canada outperform Europe.

G7 NGA Coverage, 2012

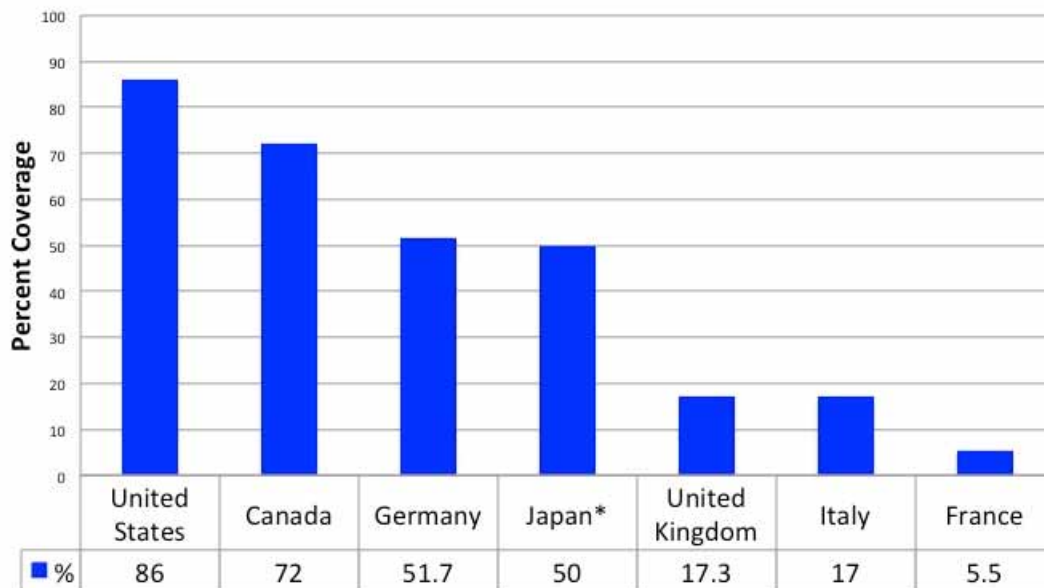


Source: NTIA, EC, MIC, CRTC

Figure 4: G7 NGA Coverage, 2012

Moving on from wired networks, LTE and LTE Advanced provide advanced mobile networking, technologies that are best developed in the U. S. and Canada.

G7 LTE Coverage, 2012

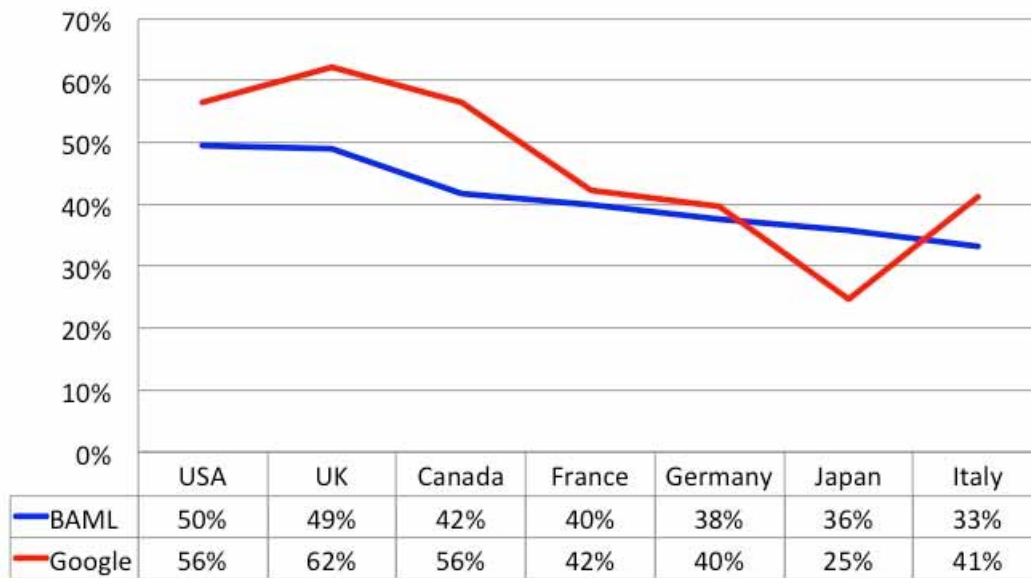


Source: NTIA, EC, CRTC, MIC

Figure 5: G7 LTE Coverage, 2012

Europe is finally rolling out LTE, just as U. S. and Canada are upgrading to the next generation, LTE Advanced. Using LTE to its peak capability requires smartphones, and we can see that their adoption isn't uniform across the G7. The U. S. and U. K. are numbers one and two on this factor, depending on which database we use, Google's or Bank of America/Merrill Lynch Wireless Matrix.

G7 Smartphone Adoption

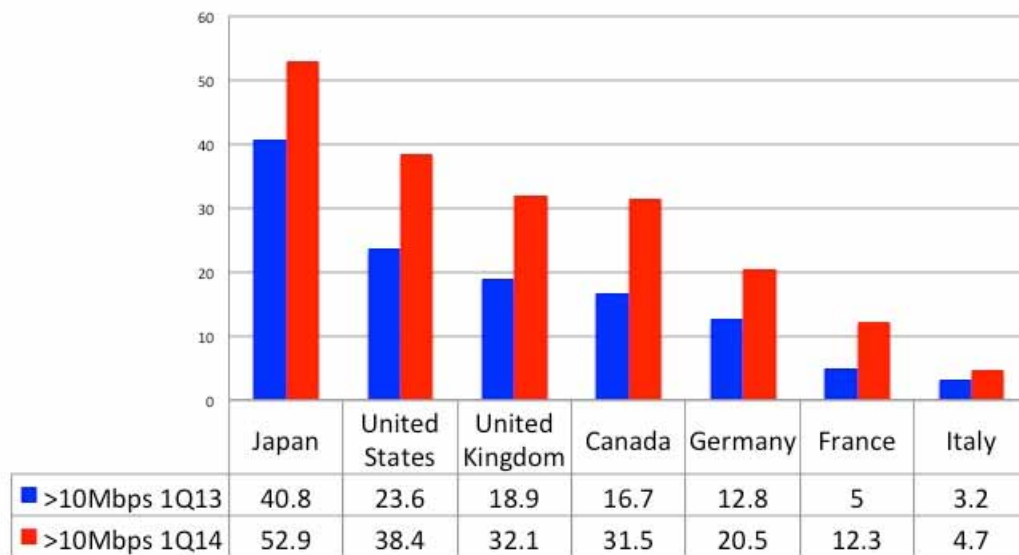


Source: Merrill Lynch, Google

Figure 6: G7 Smartphone Adoption

One of the most meaningful measurements of network technology diffusion is the percentage of connections at the highest speed tier. On wired networks, Japan and the U. S. do best here; because of the way this is measured, a network needs to have raw capacity of more than 30 Mbps for connections to exceed average performance of 10 Mbps.

G7 Wired >10 Mbps, 2013-14

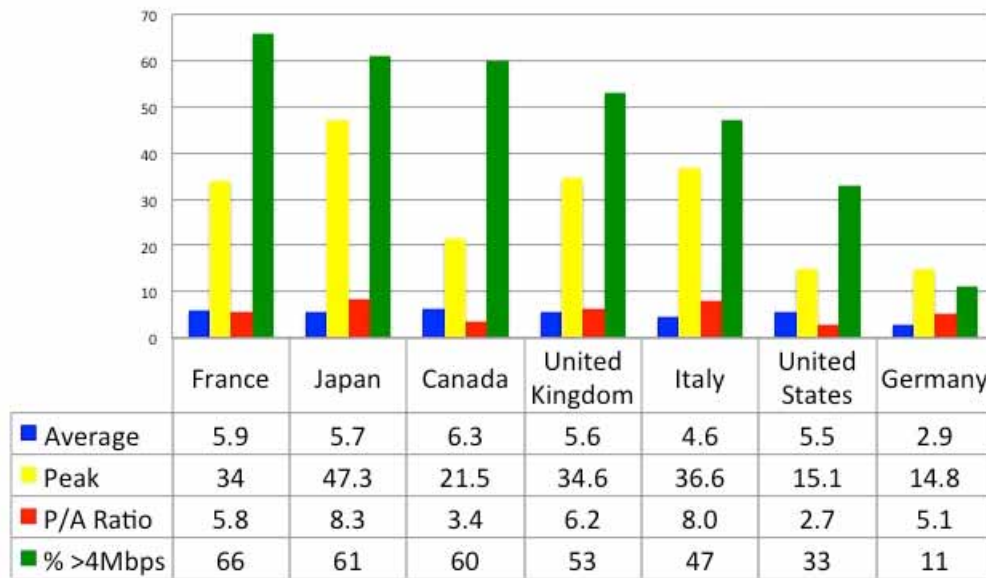


Source: Akamai

Figure 7: G7 Wired High Speed Broadband Adoption.

Wired networks are fine, but mobile is becoming the “First Screen” for most in the developed world, and in fact the only stream for many. The green bar in this graph tells us how common 4 Mbps connections are on mobile networks. In this dimension, France, Japan, and Canada are the leaders. In France, mobile networks are as fast as wired ones in some measurements; this reflects the poor quality of France’s wired infrastructure.

G7 Mobile Metrics 1Q 2014

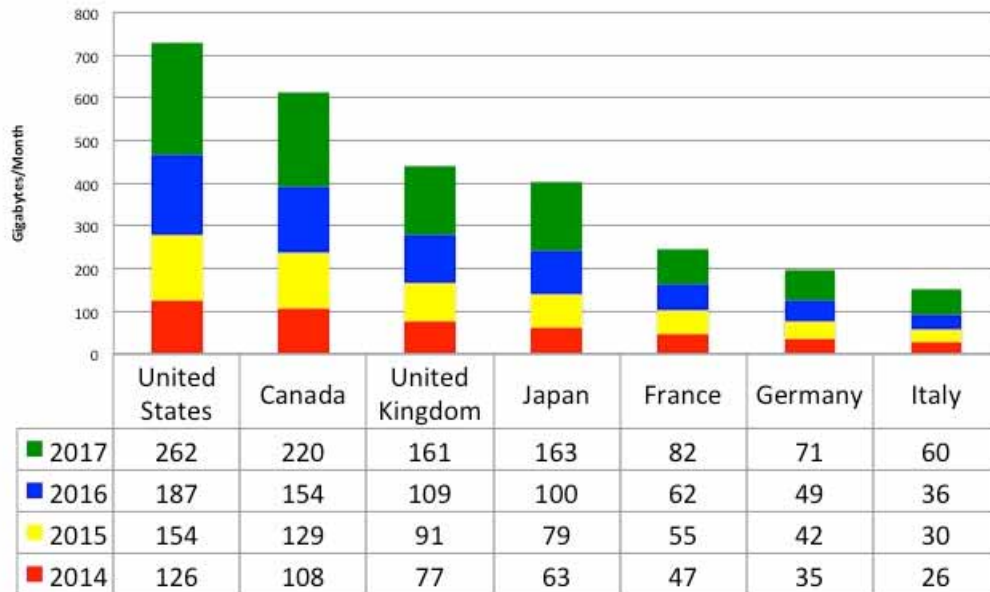


Source: Akamai

Figure 8: G7 Mobile Metrics

Good networks are nice to have, but nobody gets much benefit from them if they're not heavily used. In terms of wired network usage, the U. S. is far and away the leader in the G7.

G7 Projected Internet Traffic

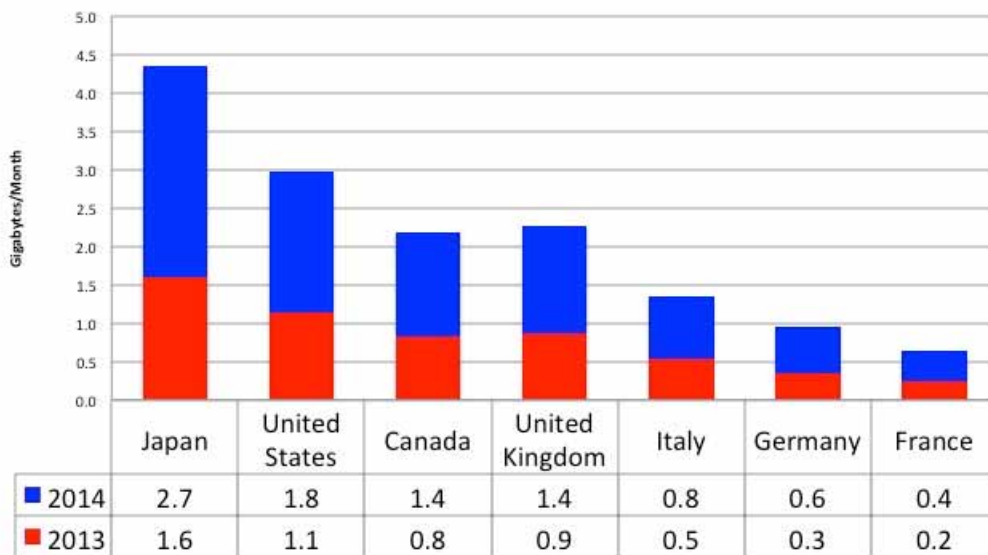


Source: Cisco

Figure 9: G7 Projected Internet Traffic

The pattern is similar for mobile usage, except Japan sneaks into the lead from fourth place in wired. This is odd because Japan is not a big smartphone nation; it suggests that people are using mobile networks from tablets and laptops in Japan as well as from smartphones. Indeed, there is some evidence that East Asian nations exhibit a new kind of “cord-cutting” where high speed broadband comes exclusively by wireless for many affluent young people.

G7 Mobile Data Usage



Source: Cisco

Figure 10: Mobile Data Usage

Heavy usage and low population density mean provider costs are higher in the U. S. and Canada than in other nations, so to judge consumer value I look at the cost of bandwidth in terms of net earnings, which represent consumer cost minus operator cost. This doesn't completely eliminate geography; Japan and U. K. are the leaders, but the U. S. and Canada do better than the other European nations.

G7 Wired Profit/Bandwidth

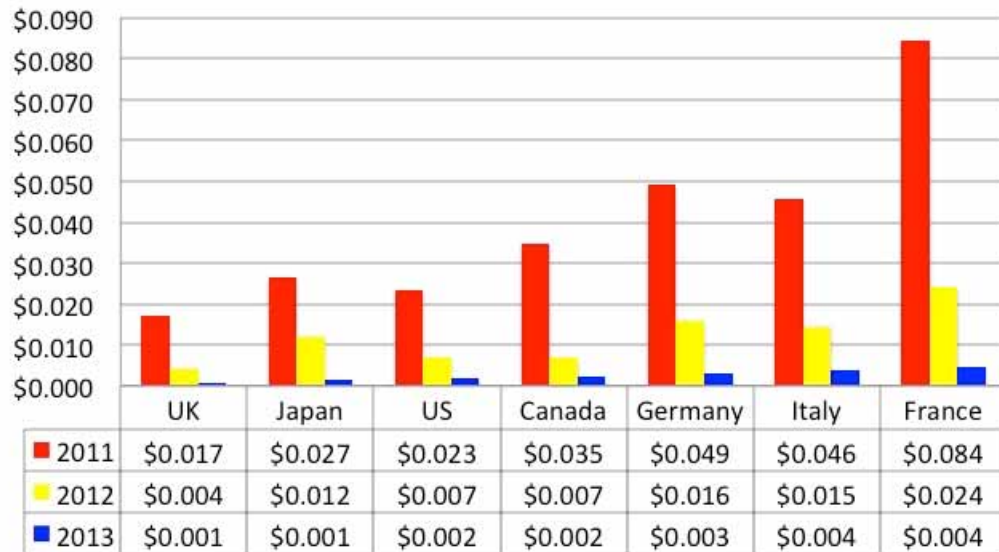


Source: Infonetics, Point Topic, Akamai, Cisco

Figure 11: G7 Dollars of profit per unit of bandwidth.

At the front of the pack, we see similar effect on mobile networks, but the order of the followers is different.

G7 Mobile Profit/Bandwidth

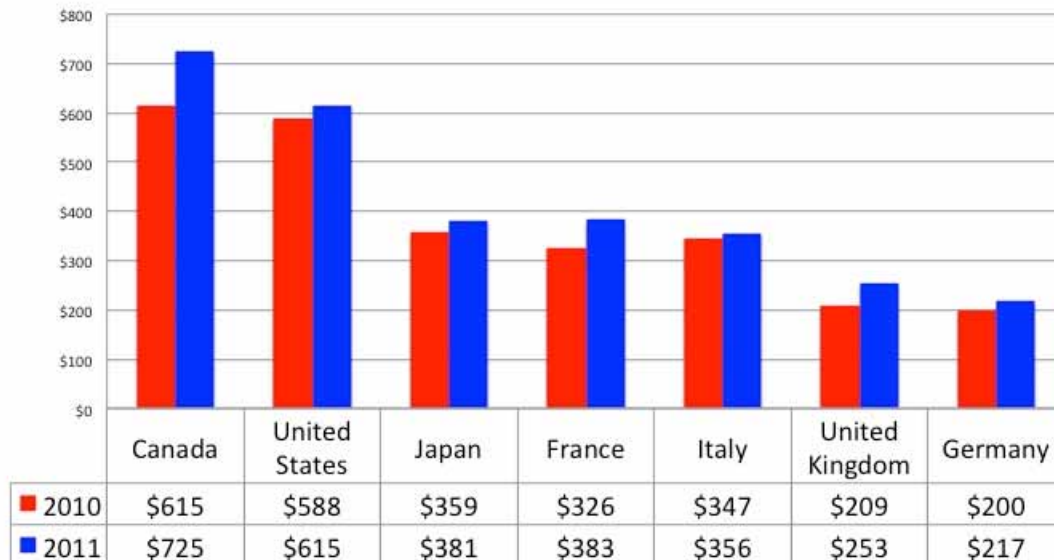


Source: Ookla, Cisco, Merrill Lynch

Figure 12: Mobile dollars of profit per unit of bandwidth

Where are we going to be tomorrow? This depends largely on investment, which is heaviest in Canada and the U. S. Geography clearly plays a role here.

G7 Telecom Investment/Household



Source: ITU

Figure 13: Broadband investment per household

This formulation doesn't tell the whole story, but at least it isolates most policy factors from non-policy factors when judging policy success. The data tell the story rather better than anecdotes do.

We can almost predict the standings on this scorecard from the state of cable TV in 1999; with the exception of Italy, the order is preserved. This does not signify that cable is the end-all and be-all of broadband; that's the status of LTE Advanced and fiber optic networks. Rather, the presence of an alternative network governed by a private carriage (rather than common carriage) regulatory framework allowed the U. S. and Canada to devise regulatory models that emphasized competition, innovation, risk capital and ingenuity above blind obedience to national plans and outdated regulatory dogma.

The study finds that the key policy variable is the ability of service providers to respond to user demand. In nations that allow vertical integration of cables, switches, routing, and interconnection, carriers are able to increase capacity at the times and places that best meet demand, and to shift from wired to wireless modalities and from lower-capacity to higher-capacity technologies as appropriate. Nations that disallow vertical integration discourage timely upgrades and complicate them by introducing coordination issues that are not easily addressed.

The menu of choices for policy makers is relatively simple: if we want a dynamic broadband marketplace in which citizens enjoy high performance networks at reasonable prices, it's necessary for regulators to be humble enough to allow the

competitive dynamic to unshackle human ingenuity. If we're content to follow the leader and move more slowly, we can adopt the Contingent Model with a micro-managing regulator, but who will be the leader if we do? If we want stagnation, we can follow the Franco-Italian "almighty regulator" approach and bemoan our lack of progress.

The data point unambiguously to the proper path.

Table of Contents

1. OVERVIEW	26
A. WHY THE G7?	26
B. BROADBAND'S ECONOMIC ROLE	27
C. BROADBAND TECHNOLOGIES	28
D. STARTING POINTS	29
I. POPULATION DISTRIBUTION	29
II. TECHNICAL INFRASTRUCTURE	33
III. POLICY FRAMEWORKS	34
E. PROGRESS	35
F. LEADERSHIP	36
2. BROADBAND COVERAGE	37
A. HOMES PASSED BY BASIC BROADBAND TECHNOLOGIES	37
I. DIGITAL SUBSCRIBER LINE (DSL)	37
II. CABLE MODEM (DOCSIS)	38
III. FIBER OPTIC BROADBAND	38
IV. 3G MOBILE BROADBAND	39
B. NUMBER OF PROVIDERS IN THE BASIC BROADBAND STAGE	39
C. NUMBER OF PROVIDERS IN THE U. S. PRESENTLY	40
D. DEPLOYMENT OF ADVANCED BROADBAND IN THE G7	41
I. ADVANCED DSL	42
II. DOCSIS 3.0	43
III. FIBER TO THE HOME	44
IV. 4G/LTE	45
E. GIGAMANIA: 1000 MBPS NETWORKING	45
I. GIGABIT PROJECTS	46
II. GIGABIT UTILITY	47
F. GROSS FIBER DEPLOYMENT	48
3. BROADBAND SUBSCRIPTION RATES	48
A. SUBSCRIPTION RATE	48
B. SUBSCRIPTION RATE BY TECHNOLOGY	49
C. WIRELESS SUBSCRIPTION RATE	51
D. SUBSCRIPTION RATE BY AGE GROUP	53

E. POLICY ISSUES	55
4. BROADBAND PERFORMANCE	55
A. APPLICATION REQUIREMENTS	56
B. WIRED NETWORK PERFORMANCE	58
I. AKAMAI TYPICAL BROADBAND SPEEDS AND ADOPTION	58
II. AKAMAI HIGH BROADBAND SPEEDS AND ADOPTION	60
III. AKAMAI AVERAGE NETWORK CAPACITY MEASUREMENT	62
IV. OOKLA WIRED NETWORK SPEED TESTS	63
V. RESOLVING WIRED MEASUREMENT DISCREPANCIES	64
C. MOBILE NETWORK PERFORMANCE	64
I. AKAMAI/ERICSSON MEASUREMENTS OF ACTUAL MOBILE BROADBAND SPEEDS	65
II. CISCO MEASUREMENT OF AVERAGE MOBILE BROADBAND SPEED	66
III. OOKLA MOBILE NETWORK SPEED SURVEY	66
IV. OPENSIGNAL LTE SPEED AND COVERAGE SURVEY	67
V. RESOLVING MOBILE MEASUREMENT DISCREPANCIES	68
D. LTE SPEED VS. COVERAGE	69
E. BROWSING SPEED	72
I. PREDICTED AVERAGE BROWSING SPEED	72
II. AKAMAI MEASUREMENTS OF ACTUAL WEB PAGE LOAD TIMES	74
F. ADVERTISED SPEED VS. ACTUAL SPEED	75
I. SAMKNOWS DATA FOR U. S. AND EUROPE	75
II. SAMKNOWS AS A SPEED SURVEY: USING AND MISUSING THE DATA	78
G. NETWORK UTILIZATION	81
5. BROADBAND PRICES	83
A. GOOD AND BAD CRITERIA	83
B. ERRORS OF SELECTION AND OMISSION	84
C. COMPREHENSIVE ADVERTISING SURVEYS	85
D. CONSUMER SURVEYS	86
E. PERCEIVED VALUE	86
6. CONSUMER VALUE	87
A. DISTANCE	87
B. VOLUME	88
C. CAPACITY	88

D. BROADBAND VALUE EQUATION	89
E. INTERNATIONAL COMPARISONS	89
F. WIRED NETWORKS	89
I. REVENUE	90
II. OPEX	90
III. CAPEX	90
IV. PRE-TAX FREE CASH FLOW	91
V. WIRED NETWORK CONSUMER VALUE	92
G. MOBILE NETWORKS	93
I. REVENUE	94
II. OPEX	96
III. CAPITAL EXPENDITURES	97
IV. PRE-TAX FREE CASH FLOW	97
V. MOBILE NETWORK CONSUMER VALUE	98
H. COMPARISONS OF SECTOR PROFITABILITY	100
I. CONTENT CREATORS	100
II. INTERNET EDGE SERVICES	101
III. NETWORK SERVICE PROVIDERS	102
IV. SUMMARY	103
I. COMPARISONS OF SECTOR TOTAL RETURN	104
I. CONTENT CREATOR	104
II. INTERNET EDGE SERVICES	105
III. NETWORK SERVICE PROVIDERS	105
IV. SUMMARY	106
J. COMPARISONS OF SECTOR RETURN ON INVESTED CAPITAL	107
I. CONTENT CREATOR	107
II. INTERNET EDGE SERVICES	108
III. NETWORK SERVICE PROVIDERS	108
IV. SUMMARY	109
K. TOTAL TELECOM INVESTMENT	110
<u>7. POLICY ANALYSIS</u>	<u>111</u>
A. INITIAL U. S. POLICY	112
B. THE GREAT PIVOT	112
C. OTHER G7 CASE HISTORIES	113

I. CANADA	114
II. JAPAN	114
III. EUROPEAN COMMISSION DIRECTIVES	117
IV. UNITED KINGDOM	118
V. GERMANY	120
VI. FRANCE	123
VII. ITALY	125
8. SUMMARY OF RESULTS	126
9. CONCLUSION	127
ACKNOWLEDGEMENTS	128
ENDNOTES	129

Table of Figures

FIGURE 1: INTERNET HEAT MAP. SOURCE: SHODAN (HTTPS://WWW.SHODAN.IO)	2
FIGURE 2: G7 BROADBAND SCORECARD STANDINGS	5
FIGURE 3: G7 RURAL AREA PER INTERNET EXCHANGE	6
FIGURE 4: G7 NGA COVERAGE, 2012	7
FIGURE 5: G7 LTE COVERAGE, 2012	8
FIGURE 6: G7 SMARTPHONE ADOPTION	9
FIGURE 7: G7 WIRED HIGH SPEED BROADBAND ADOPTION.	10
FIGURE 8: G7 MOBILE METRICS	11
FIGURE 9: G7 PROJECTED INTERNET TRAFFIC	12
FIGURE 10: MOBILE DATA USAGE	13
FIGURE 11: G7 DOLLARS OF PROFIT PER UNIT OF BANDWIDTH.	14
FIGURE 12: MOBILE DOLLARS OF PROFIT PER UNIT OF BANDWIDTH	15
FIGURE 13: BROADBAND INVESTMENT PER HOUSEHOLD	16
FIGURE 14: INTERNET HEAT MAP. SOURCE: SHODAN (HTTPS://WWW.SHODAN.IO)	26
FIGURE 15: G7 SHARE OF POPULATION IN MOST POPULATED 10 PERCENT OF REGIONS. SOURCE: OECD FACTBOOK.	30
FIGURE 16: G7 URBAN POPULATION DISTRIBUTION IN PERCENT. SOURCE: OECD FACTBOOK.	30
FIGURE 17: G7 URBAN DENSITY INDEX. SOURCE: ITIF, DEMOGRAPHIA.	31
FIGURE 18: G7 RURAL PERSONS PER SQ. KM. ARABLE LAND. SOURCE: WORLD BANK	32
FIGURE 19: RURAL AREA SERVED BY EACH IXP IN NATION OR NEARBY. SOURCE: AUTHOR'S CALCULATIONS FROM WORLD BANK AND PEERINGDB.	32

FIGURE 20: CABLE TV COVERAGE IN 1999. SOURCE: OECD	33
FIGURE 21: MOBILE SUBSCRIPTIONS PER 100 PEOPLE IN 1999. SOURCE: WORLD BANK	34
FIGURE 22: G7 DSL COVERAGE IN 2009 (EXCEPT AS NOTED). SOURCE: OECD	37
FIGURE 23: G7 CABLE MODEM COVERAGE IN 2008. SOURCE: OECD AND *JCTEA	38
FIGURE 24: G7 FIBER COVERAGE IN 2009 AND 2012. SOURCE: OECD, NTIA, EC, CRTC.	38
FIGURE 25: G7 3G MOBILE COVERAGE IN 2009. SOURCE: OECD	39
FIGURE 26: G7 BI-MODAL COMPETITION IN 2009. SOURCE: OECD	39
FIGURE 27: G7 TRI-MODAL COMPETITION IN 2009. SOURCE: OECD	40
FIGURE 28: U. S. URBAN VS. RURAL BROADBAND COMPETITION. SOURCE: NTIA.	40
FIGURE 29: U. S. ACCESS TO MULTIPLE WIRED BROADBAND CHOICES. SOURCE: NTIA.	41
FIGURE 30: G7 NGA COVERAGE AND URBAN POPULATION 2012. SOURCES: EC, NTIA, MIC, CRTC, WORLD BANK.	42
FIGURE 31: U. S. URBAN AND RURAL BROADBAND BY CAPACITY, 2012. SOURCE: NTIA.	42
FIGURE 32: G7 VDSL COVERAGE 2012. SOURCE: EC, NTIA, CRTC	43
FIGURE 33: G7 DOCSIS 3.X COVERAGE 2012. SOURCE: EC, NTIA, CRTC, JCTEA. JAPAN FROM 2010, CANADA ESTIMATED.	44
FIGURE 34: G7 FTTH COVERAGE, 2012. SOURCE: EC, NTIA, MIC, FTTH COUNCIL. CANADA ESTIMATE	45
FIGURE 35: LTE COVERAGE IN 2012. SOURCE: EC, NTIA, CRTC. *JAPAN ESTIMATED.	45
FIGURE 36: U. S. GIGABIT NETWORK DEPLOYMENTS. SOURCE: GIG.U.	47
FIGURE 37: G7 WIRED BROADBAND SUBSCRIPTION RATE. SOURCE: OECD.	49
FIGURE 38: WIRED BROADBAND SUBSCRIPTION RATE BY POPULATION AND TECHNOLOGY, 2013. SOURCE: OECD. *UK AND US ESTIMATED BY OECD.	49
FIGURE 39: FIBER SUBSCRIPTIONS AS PERCENT OF ALL BROADBAND SUBSCRIPTIONS. SOURCE: OECD.	50
FIGURE 40: G7 FTTX COVERAGE AND TAKEUP. SOURCE: OECD, MIC, WORLD BANK, NTIA, NATIONBUILDER, EC. NOTE: TAKE-UP RATE CALCULATED ON THE BASIS OF TOTAL FTTX SUBSCRIPTIONS DIVIDED BY TOTAL HOUSEHOLDS WITH FTTX COVERAGE. UK FIGURES INCLUDE VDSL.	51
FIGURE 41: G7 SMARTPHONE ADOPTION. SOURCE: BAML WIRELESS MATRIX AND MOBILE PLANET BY GOOGLE.	51
FIGURE 42: G7 BROADBAND ADOPTION GROWTH BY TECH. SOURCE: OECD.	52
FIGURE 43: G7 BROADBAND ADOPTION GROWTH BY TECH, DETAILS. SOURCE: OECD.	53
FIGURE 44: SENIORS ARE TECHNOLOGY AVERSE. SOURCE: PEW.	53
FIGURE 45: OLDER SENIORS ARE MORE TECHNOLOGY-AVERSE THAN YOUNGER ONES. SOURCE: PEW.	54
FIGURE 46: U. S. INTERNET USE IN THOUSANDS BY AGE AND COMPUTER OWNERSHIP: 21011. SOURCE: CENSUS	54
FIGURE 47: DOWNLOAD TIMES FOR ENTERTAINMENT MEDIA FILES. SOURCE: SAUNDERS ET AL.	57
FIGURE 48: MEDIUM-CAPACITY BROADBAND PREVALENCE, 2007-14. SOURCE: AKAMAI.	59

FIGURE 49: G7 PERCENT CONNECTIONS >4MBPS 1Q 2013-14. SOURCE: AKAMAI	60
FIGURE 50: HIGH CAPACITY BROADBAND PREVALENCE, 2007-14. SOURCE: AKAMAI.	61
FIGURE 51: PERCENT CONNECTIONS >10MBPS Q1 2013-14. SOURCE: AKAMAI	61
FIGURE 52: NETWORK CAPACITY IN G7 NATIONS, 2007-14. SOURCE: AKAMAI	62
FIGURE 53: G7 BROADBAND CAPACITIES IN Q1 2014. SOURCE: AKAMAI.	63
FIGURE 54: OOKLA SURVEY OF G7 WIRED NETWORK SPEED. SOURCE: OOKLA.	64
FIGURE 55: G7 MOBILE BROADBAND SPEED 1Q 2014. SOURCE: AKAMAI	65
FIGURE 56: AVERAGE G7 MOBILE DOWNLOAD SPEED, AUGUST 2013. SOURCE: CISCO.	66
FIGURE 57: G7 OOKLA MOBILE DOWNLOAD SPEED. SOURCE: OOKLA.	67
FIGURE 58: G7 OPENSIGNAL LTE SPEED SURVEY. SOURCE: OPENSIGNAL	67
FIGURE 59: G7 MOBILE SPEED TEST SCORES. SOURCE: AKAMAI, OOKLA, OPENSIGNAL.	69
FIGURE 60: G7 OPENSIGNAL LTE SPEED BY NETWORK. SOURCE: OPENSIGNAL	70
FIGURE 61: G7 OPENSIGNAL LTE SPEED BY NETWORK. SOURCE: OPENSIGNAL.	71
FIGURE 62: G7 OPENSIGNAL LTE SPEED AS FUNCTION OF COVERAGE SOURCE: OPENSIGNAL	71
FIGURE 63: BROWSING EXPERIENCE IN G7 NATIONS, 2007-14. SOURCE: AKAMAI.	72
FIGURE 64: AVERAGE SIZE OF WEB PAGES, MAY 15, 2014. SOURCE: HTTP ARCHIVE.	73
FIGURE 65: G7 WEB SPEED AND PAGE LOAD TIME. SOURCE: HTTP ARCHIVE, AKAMAI, CALCULATION.	74
FIGURE 66: G7 WEB PAGE LOAD TIME BY NETWORK TYPE. SOURCE: AKAMAI	74
FIGURE 67: SAMKNOWS PROMISE INDEX FOR U. S. BY TECHNOLOGY, SEPT. 2012. SOURCE: FCC.	75
FIGURE 68: SAMKNOWS PROMISE INDEX FOR EUROPE, MARCH 2012. SOURCE: EC.	76
FIGURE 69: SAMKNOWS PROMISE INDEX FOR EUROPE, MARCH 2013. SOURCE: EC.	76
FIGURE 70: SAMKNOWS PROMISE INDEX FOR G7 COUNTRIES. SOURCE: EC, FCC.	77
FIGURE 71: SAMKNOWS TESTING OF ROGERS CABLE CANADA, MAY 2013. SOURCE: ROGERS CABLE.	78
FIGURE 72: G7 SAMKNOWS SPEED BY TECHNOLOGY. SOURCE: OECD, EC, FCC.	80
FIGURE 73: SAMKNOWS G7 DOWNLOAD SPEED TIMES MARKET SHARE. SOURCE: OECD, EC, FCC. *SAMKNOWS DOES NOT MEASURE SPEEDS HIGHER THAN 75 MBPS IN THE U. S., AND U. K. DOES NOT OFFER CABLE SPEEDS LESS THAN 50 MBPS. CORRECTION INCREASES U. S. AVERAGE FROM 18.18 TO 25 MBPS TO ACCOUNT FOR THIS ARBITRARY EXCLUSION. MARKET SHARE FIGURES FROM OECD.	81
FIGURE 74: PROJECTED INTERNET TRAFFIC IN GIGABYTES PER HOUSEHOLD PER MONTH. SOURCES: CISCO, WORLD BANK, AND NATIONMASTER.	82
FIGURE 75: G7 ESTIMATED MOBILE DATA USAGE PER HOUSEHOLD. SOURCES: CISCO, WORLD BANK, AND NATIONMASTER.	82
FIGURE 76: OECD PRICE COMPARISONS FOR G7 NATIONS. SOURCE: OECD.	83
FIGURE 77: TRIPLE-PLAY PRICES IN SOME G7 CITIES AND TOWNS, INCLUDING CONTENT FEES. SOURCE: NEW AMERICA, LAYTON	85
FIGURE 78: BROADBAND PRICES BY SPEED, U. S. AND EU 2012. SOURCE: VAN DIJK	85

FIGURE 79: AVERAGE MONTHLY BROADBAND PRICES FOR STANDALONE RESIDENTIAL SERVICES IN Q1 2014. SOURCE: POINT TOPIC.	86
FIGURE 80: G7 INTERNET COST, PERCEIVED VALUE, AND CONTRIBUTION TO GDP. SOURCE: BOSTON CONSULTING GROUP	87
FIGURE 81: G7 WIRED OPEX PERCENT OF REVENUE. SOURCE: INFONETICS AND AUTHOR'S ANALYSIS.	90
FIGURE 82: CAPEX AS PERCENT OF INCOME FOR G7 WIRED BROADBAND FIRMS. SOURCE: INFONETICS	91
FIGURE 83: G7 WIRED BROADBAND PRE-TAX FREE CASH FLOW AS PERCENT OF INCOME. SOURCE: INFONETICS	92
FIGURE 84: G7 WIRED BROADBAND END USER BANDWIDTH PRICE IN DOLLARS OF PROFIT. SOURCE: INFONETICS, POINT TOPIC, AKAMAI, CISCO.	93
FIGURE 85: G7 END USER BANDWIDTH PRICE AFTER INVESTMENT. SOURCE: ITU, POINT TOPIC, AKAMAI, CISCO.	93
FIGURE 86: G7 MOBILE AVERAGE REVENUE PER USER. SOURCE: INFONETICS	94
FIGURE 87: G7 MOBILE ARPU AS PERCENT OF GDP. SOURCE: MOBILE MATRIX.	95
FIGURE 88: G7 SMARTPHONE ADOPTION AND USE. SOURCE: MOBILE MATRIX.	96
FIGURE 89: G7 MOBILE OPEX AS PERCENT OF REVENUE. SOURCE: MOBILE MATRIX	96
FIGURE 90: G7 MOBILE CAPEX AS PERCENT OF INCOME. SOURCE: MOBILE MATRIX	97
FIGURE 91: G7 MOBILE PRE-TAX FREE CASH FLOW AS PERCENT OF INCOME. SOURCE: MOBILE MATRIX	98
FIGURE 92: G7 MOBILE BROADBAND BANDWIDTH PRICE IN DOLLARS OF PROVIDER PROFIT. SOURCE: AUTHOR CALCULATIONS ON DATA FROM OOKLA, CISCO, BAML.	99
FIGURE 93: G7 MOBILE BROADBAND BANDWIDTH PRICE IN DOLLARS OF PROVIDER REVENUE. SOURCE: AUTHOR CALCULATIONS ON DATA FROM OOKLA, CISCO, BAML AND INFONETICS.	99
FIGURE 94: U. S.-BASED CONTENT CREATOR PROFITABILITY. SOURCE: FIDELITY RESEARCH	101
FIGURE 95: U. S.-BASED INTERNET INTERMEDIARY PROFITABILITY. SOURCE: FIDELITY RESEARCH	102
FIGURE 96: U. S.-BASED CARRIER PROFITABILITY. SOURCE: FIDELITY RESEARCH	103
FIGURE 97: U. S.-BASED CONTENT CREATOR TOTAL PERCENT RETURN. SOURCE: FIDELITY RESEARCH	104
FIGURE 98: U. S.-BASED INTERNET INTERMEDIARY TOTAL PERCENT RETURN. SOURCE: FIDELITY RESEARCH	105
FIGURE 99: U. S.-BASED BROADBAND CARRIER TOTAL PERCENT RETURN. SOURCE: FIDELITY RESEARCH.	106
FIGURE 100: U. S.-BASED CONTENT CREATOR RETURN ON INVESTED CAPITAL. SOURCE: BLOOMBERG	107
FIGURE 101: U. S.-BASED INTERNET EDGE SERVICES RETURN ON INVESTED CAPITAL. SOURCE: BLOOMBERG.	108
FIGURE 102: U. S.-BASED NETWORK SERVICES RETURN ON INVESTED CAPITAL. SOURCE: BLOOMBERG	109
FIGURE 103: SECTOR AVERAGE ROIC. SOURCE: BLOOMBERG	110

FIGURE 104: G7 TELECOM INVESTMENT PER CAPITA. SOURCE: ITU	111
FIGURE 105: G7 TELECOM INVESTMENT PER HOUSEHOLD. SOURCE: ITU	111
FIGURE 107: ICT INITIATIVES OF THE JAPANESE GOVERNMENT.	116
FIGURE 108: BROADBAND AVAILABILITY AMONG JAPANESE HOUSEHOLDS. SOURCE: MIC NOTE: NUMBERS IN PARENTHESES ARE HOUSEHOLD COVERAGE BY FIXED BROADBAND.	116
FIGURE 110: G7 BROADBAND SCORECARD (LOWER IS BETTER)	127

1. Overview

This study evaluates the quality, dynamism, and value of America's broadband network infrastructure against relevant international competitors in order to determine how well the various regulatory models are working. It judges policy success according to two primary factors:

- 1) The build-out and utilization of advanced networks of sufficient quality to enable consumers to use state-of-the-art applications and to enjoy extensive access to content.
- 2) The profitability of broadband suppliers and the extent of their ongoing investment in the broadband infrastructure.

In addition to these primary factors, the study examines several secondary indicators, such as population distribution, smartphone adoption, Next Generation Access (NGA) deployment, competition, rural coverage, fiber deployment, gigabit networks, adoption growth, technology use by age group, download times, network capacity, LTE coverage, web page load times, the SamKnows Promise Index, projected traffic growth, pricing, perceived value, financials, and policy model details.

A. Why the G7?

This study compares the condition of America's broadband ecosystem against other members of the G7 for two reasons: because G7 nations are the most comparable, and because the G7 is where the action is. The Internet Heat Map shows the greatest concentration of Internet-connected devices is in the G7.

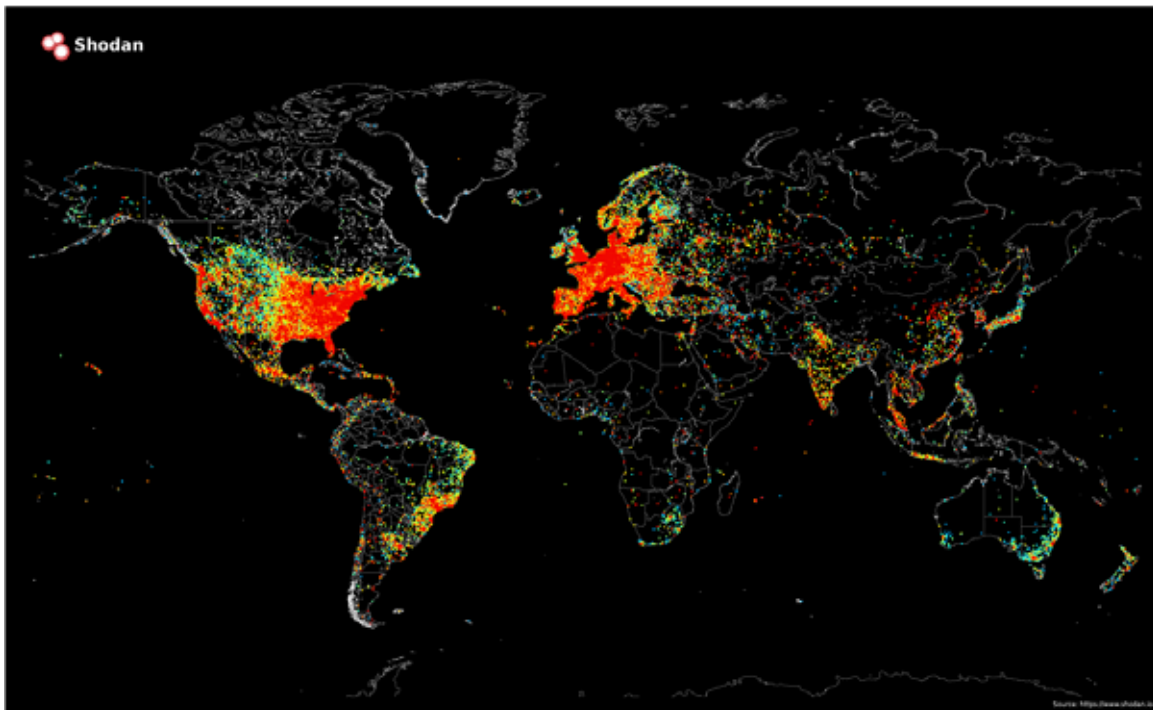


Figure 14: Internet Heat Map. Source: Shodan (<https://www.shodan.io>)

The goal of the study is to determine whether America's broadband policies are producing the desired results to a greater or lesser degree than those employed by comparable nations.

The study examines the effects of the three policy models in effect in the G7:

- 1) The "Pioneer Model" used by the U. S. and Canada.
- 2) The "Contingent Model" used in Japan, Germany, and U. K.
- 3) The "Utility Model" used in France and Italy.

The study finds that disparities in broadband performance and carrier profitability cannot be accounted for strictly on the basis of policy, for three reasons:

- 1) Each nation entered the broadband era with a different level of inherited infrastructure, some of which was more suitable for broadband deployment than the rest.
- 2) Each nation has different cost factors irrespective of inherited infrastructure, such as population distribution (especially the concentration of population into extremely high-density or low-density areas,) and distance from key Internet Exchange Points.
- 3) Interest in and preparation for use of the Internet depends on demographic factors such as the education, income, and age of the population; English language skills; and attitudes toward technology. These vary considerably across nations.

The study finds that the key policy variable is the ability of service providers to respond to user demand. In nations that allow vertical integration of cables, switches, routing, and interconnection, carriers are able to increase capacity at the times and places that best meet demand, and to shift from wired to wireless modalities and from lower-capacity to higher-capacity technologies as appropriate. Nations that disallow vertical integration discourage timely upgrades and complicate them by introducing coordination issues that are not easily addressed.¹

B. Broadband's Economic Role

Broadband networks are parts of a market for information services and content. Networks serve as platforms for end-user services such as personal communication, publishing, entertainment, education, health care, and the like. Networks are not ends in themselves, but platforms in a rich ecosystem of innovation that enables economic growth, personal fulfillment, high quality of life, and host of other benefits.

Networks must be powerful and capable enough to enable applications; to the extent that applications are hobbled by or forced to adapt to network conditions, networks are problematic. To the extent that innovators and users are able to create and enjoy valuable applications, networks are successful.

A number of attempts have been made to quantify the effects that broadband quality has on economic growth and development, but none of them is completely satisfying.² Broadband networks are parts of a broad market for Information and Communication Technology (ICT) services, not the entire market. As the ITU study *Impact of Broadband on the Economy* points out, broadband interacts with the economy in several ways. It requires critical mass, it is most effective at lowering transaction costs, produces fastest results in large firms, and is primarily valuable when it stimulates new applications. Its impact is neither instant nor automatic.³

The need to develop innovation-friendly policies to enhance the power of networking to develop economies is documented in a number of long-running, reputable studies by organizations such as the Economist Economic Intelligence Unit, INSEAD, and the World Economic Forum, ranking nations on their use of ICTs to create jobs and stimulate economic growth.

Each of these studies assigns a relatively small fraction of ICT readiness to broadband network quality and price: typically, 20 percent or less.⁴ INSEAD, for example, lumps network factors such as capacity, price, and international bandwidth into a category that includes content accessibility, electricity, and digital literacy; altogether, these factors account for a quarter of the total index.⁵

It's therefore prudent to understand that the overall market for ICT services is a diverse blend of factors that includes demand, investment, utilization, tax policy, regulatory inclination, and applications. It is therefore misleading to simply rank nations on broadband speed; it's quite evident that diffusion of competent networks and broad adoption of networks are much more important to society and the economy than a few people enjoying the absolutely most technically advanced connections.

In any case, economic analysis of the connection between broadband capacity and GDP is outside the scope of this study, which focuses on the impact of regulation on the dynamism of broadband markets.

C. Broadband Technologies

While "fast" networks (those with high capacity and low delay) are generally preferable to slow ones, there is a point of diminishing returns in broadband capacity. This becomes evident in examining the current mania for ultra-high-capacity "gigabit" networks (those with capacities of 1000 megabits per second or more). Most of world's broadband residential networks in urban and suburban areas have peak capacities of 10 - 100 Mbps today, and the common use of gigabit networks is for aggregation of end-user links rather than as an end-user link in its own right. Widely used broadband technologies include:

- Hybrid twisted pair copper/fiber networks (using VDSL2+ and copper loop lengths of 3,000 feet or less) that provide each customer with 40 - 50 Mbps of unshared capacity over bonded pairs or half as much over single pairs
- Hybrid coaxial copper cable/fiber networks using DOCSIS 3.0 that provide 160 Mbps of shared capacity and 20 - 100 Mbps to each connection.
- LTE and LTE Advanced mobile networks providing 10 - 100 Mbps of capacity to each user.
- Optical Ethernet, a fiber- and switch-based aggregation technology running at speeds from 100 Mbps to 400 Gbps.
- Passive Optical Networking (xPON), a passive fiber optic residential technology typically providing connection capacity of 20 - 1000 Mbps.

It should be noted that these technologies were principally invented and developed in the U. S. Gigabit networks use xPON fiber to the home (FTTH) today, and may be provided over copper/fiber hybrids in the near future.

Neighborhood network capacity is balanced with capacity in other parts of the Internet. High last mile capacity is wonderful, but so are Content Delivery Networks, local caches, image-reformatting services, increased middle mile capacity, and better connections to Internet Exchange Points.

To the extent that service providers over-invest in last mile capacity, they may under-invest in capacity improvements in other parts of their networks. If each residence has a 1 Gbps connection but the common Internet Exchange port remains at 10 Gbps (the current norm), gigabit customers will not achieve increased performance across the expanse of the entire Internet. The FCC's SamKnows studies of web page loading times on today's Internet suggest that today's common networks already outperform today's common web servers; at connection speeds of 25 Mbps, server and browser limitations rather than network factors cause 60 percent of the web page load time users experience.⁶

There is good reason to believe that both Korea and Japan have over-provisioned residential capacities and under-provisioned inter-network capacities, but the data on this subject is somewhat sparse and ambiguous; one telling example is the Net Index by Ookla (Speedtest.net) crowd-sourced broadband capacity measurement that ranks Japan fifth in the G7 in terms of download speed despite the ubiquitous deployment of 100 Mbps FTTH/B services in that country.⁷ Crowd-sourced measurements are unreliable, so this conclusion is dubious.

D. Starting Points

Nations did not enter the broadband era on equal footing. Some countries – the U. S., Canada, Belgium and Netherlands in particular – had widely deployed cable TV networks in the late 1990s, but most did not.⁸ The former Soviet satellites not only did not have cable TV, their telephone networks were sparsely deployed and of poor quality; the USSR did not place a high premium on free speech and entertainment.

Nations with low-density housing norms, such the U. S., tended to have longer copper wire lengths than high-density nations, and distance is the enemy of network capacity. Fortunately, fiber and coaxial cable overcome many of the effects of a dispersed population and those nations with low density had more reason to install coaxial cable for television viewing than those with higher urban concentration.

The widespread existence of coaxial cable serves as an impediment to fiber deployment because coaxial is capable of achieving very high speeds. The modern digital cable system already transmits three to six gigabits of digital TV information each second and can offer gigabit speed for Internet access by reassigning channel capacity from TV to broadband.

i. Population Distribution

Costs of broadband and upgrade progress rates are largely a function of bandwidth and distance, where rural regions and heavy users are more expensive to serve. Rural costs are high because of cabling and switching costs and the difficulty in sharing facilities such as wire and switches. High-volume users require additional aggregation capacity, and even super-dense cities can be problematic where there is overcrowding in shared ducts and conduits. The addition of dedicated telephone lines to support fax machines in the 1980s and modems in the 1990s jammed conduits in New York and similar cities. Switching from copper to fiber alleviates conduit overcrowding.

The distribution (rather than the average density) of the U. S. population at the start of the broadband era raised difficulties for broadband deployment and upgrade. Compared to other G7 nations, the U. S. has the second highest concentration of population in the ten percent of most populated regions and the second lowest rural density.

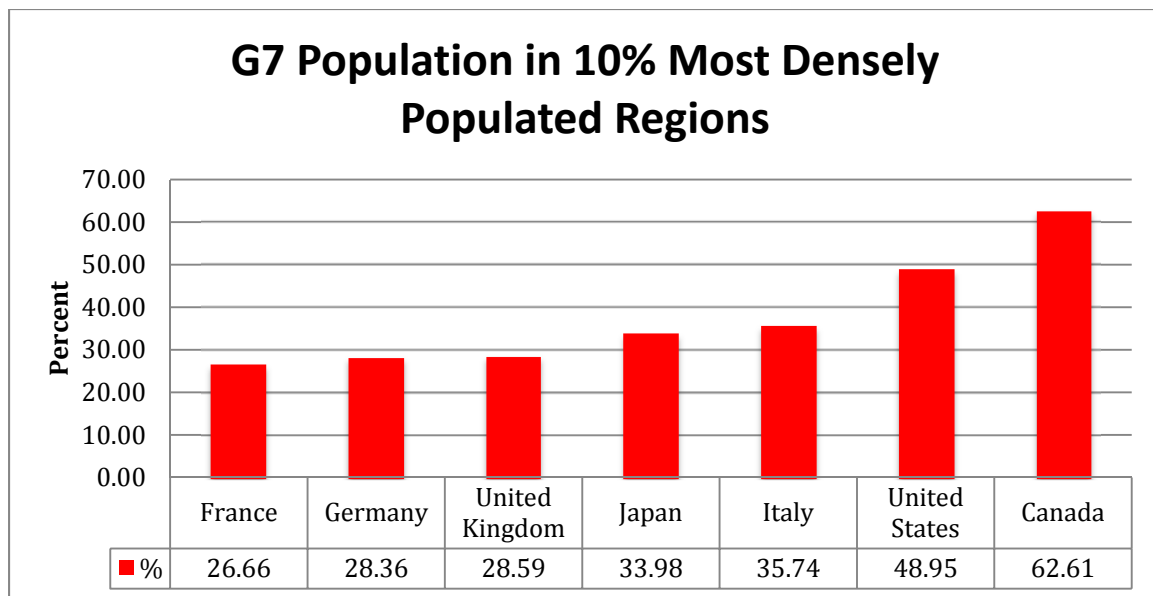


Figure 15: G7 Share of population in most populated 10 percent of regions. Source: OECD Factbook.⁹

The U. S. also has the median proportion of rural population in the G7. Italy, Germany, and France stand out for their large rural populations, signaling problems with broadband deployment, but these nations have more evenly distributed populations than Canada and the U. S.

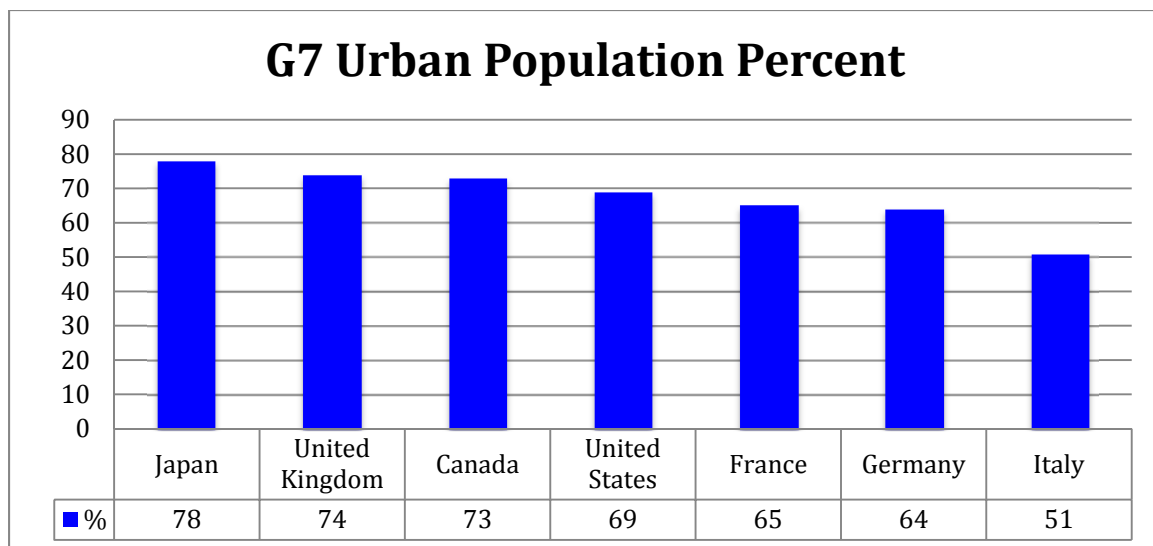


Figure 16: G7 Urban population distribution in percent. Source: OECD Factbook.¹⁰

The combination of these two charts says that the rural population in the U. S. is both relatively large (as a proportion of total population) compared to the rest of the G7 and also significantly more dispersed. Canada has an even more dispersed rural population than the U. S., but it does not have as many rural residents as a proportion of total population as does the U. S.

Italy, Germany, and France have proportionately more rural residents than the U. S., but their rural regions are not as dispersed as those in Canada and the U. S. To put this

finding in simple terms, the U. S. has a lot more people living on 10-acre lots than other countries do, and a lot fewer living in high-rise apartment buildings.

A quick examination of population distribution is included in the *Whole Picture* report produced by ITIF in 2013. It studies the relative density of cities in OECD nations, from which we can extract data relevant to the G7.¹¹

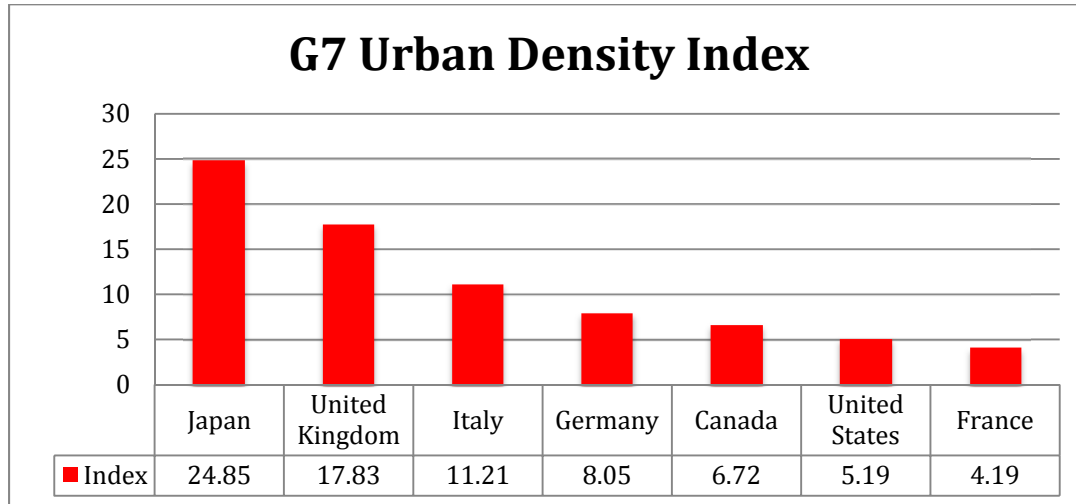


Figure 17: G7 Urban Density Index. Source: ITIF, Demographia.¹²

The ITIF urban density index is an assessment of the mean density of all urban and suburban areas with more than 1000 people per square mile.¹³ A highly concentrated urban population profile reduces costs to serve urban residents - new fiber costs less than \$200 per residence passed in Hong Kong vs. \$700 - \$2000 per residence in U. S. cities and suburbs. It also increases costs to serve each rural resident; on net, high urban density reduces nationwide service costs, especially when rural population is low.

Perhaps the best way to assess population distribution is in terms of the rural density rather than urban/suburban density. By number of rural residents per square kilometer of arable land, a standard measure in population studies, we see stark contrasts within the G7, ranging from near 1000 (the high limit by definition) in Japan to 14 in Canada.

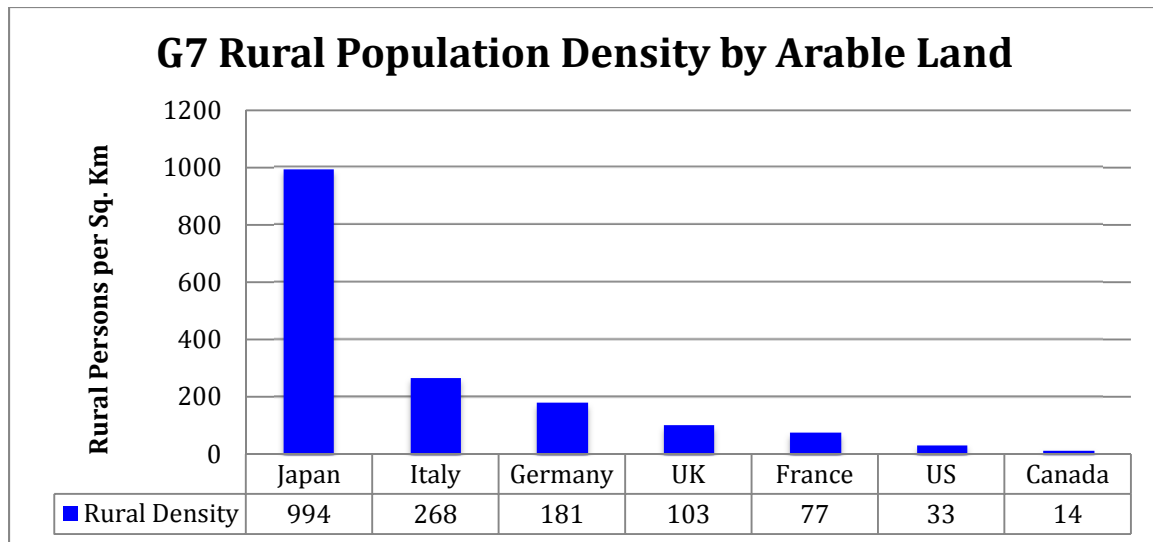


Figure 18: G7 Rural persons per sq. km. arable land. Source: World Bank¹⁴

While much of the U. S. population lives in relatively high-density areas, our urban centers are less concentrated than those in most G7 nations and our rural residents are much more dispersed as well. While the G7 nations are roughly comparable, there are still meaningful differences in several dimensions of comparison.

Superficial examination suggests that distance to major Internet Exchanges varies considerably across the G7. This factor has a major impact on service costs. An approximate measure - derived from the number of exchanges per nation, the rural population, and average rural density - suggests a range from 14,082 square km per exchange in Japan to 222,236 in Canada, with the U. S. at the high end with 185,924.

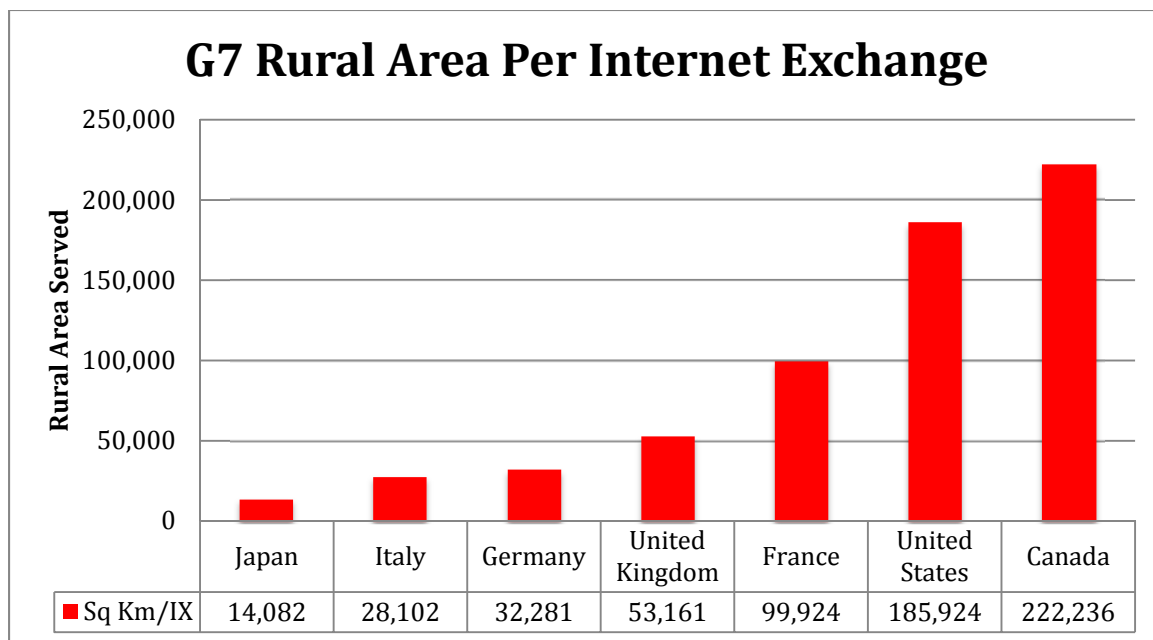


Figure 19: Rural area served by each IXP in nation or nearby. Source: author's calculations from World Bank and PeeringDB¹⁵.

This is not a precise tally, but it's clear that a dispersed population is more expensive to serve with wired broadband than a compact one. The dispersed rural population is one reason the U. S. installs more new fiber optic cable each year than any comparable region.¹⁶

ii. Technical Infrastructure

Before broadband, most homes in the G7 were wired for telephone service, and some were wired for cable TV. The United States, Canada, Japan, and the U. K. led the G7 in cable deployment, and the OECD average deployment was roughly half the U. S. deployment.¹⁷

The starting point suggested that DSL would become the most popular form of broadband for developed nations since its physical wiring was most prevalent. It also suggested that the U. S. and Canada, and to a lesser extent, the U. K., would be excellent candidates for a facilities-based competition model, but other countries would not be.

The dearth of cable in most of the developed world also suggested that fiber networks would be likely to appear earlier in non-cable countries, since the greater capacity of cable would make fiber builds less attractive where it existed and fiber more compelling where it didn't.

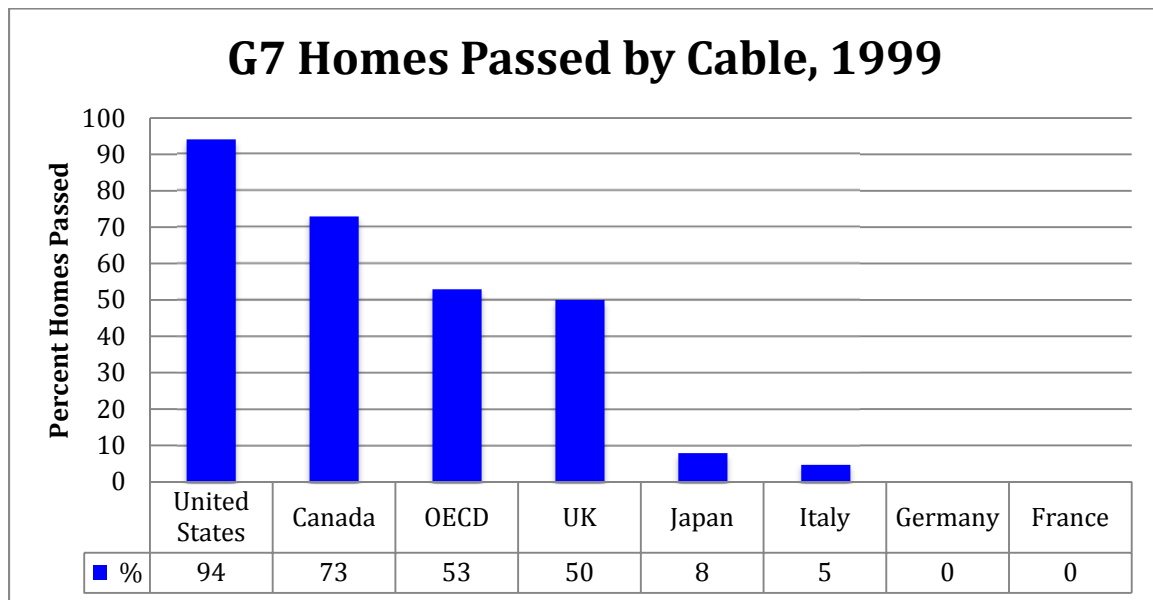


Figure 20: Cable TV Coverage in 1999. Source: OECD¹⁸

While the U. S. led the G7 in cable TV in 1999, it was only middling in cellular telephone deployment, a trend that took off most rapidly in nations with poor wired telephone service.

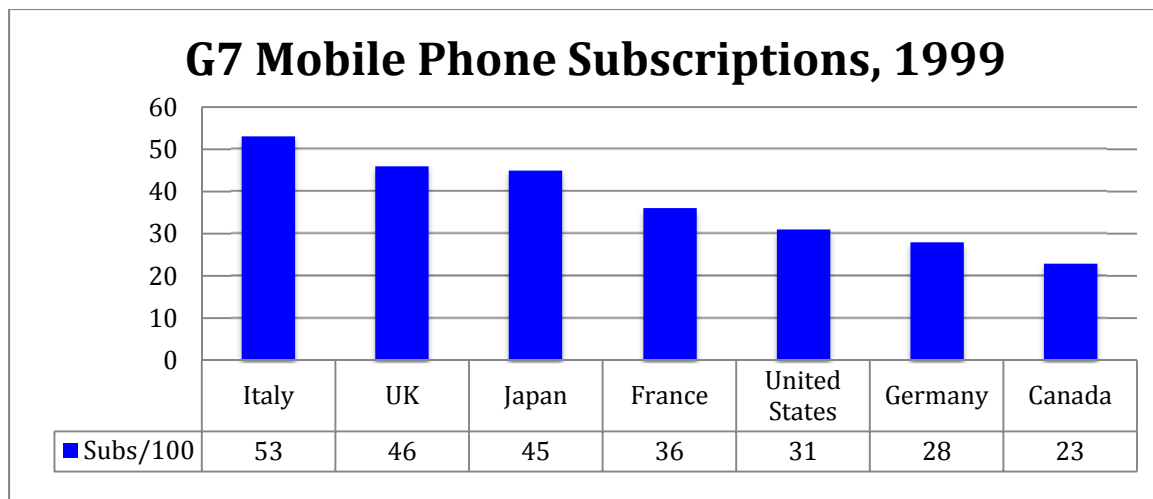


Figure 21: Mobile Subscriptions per 100 people in 1999. Source: World Bank¹⁹

At the end of 1999, 120 geostationary satellites were in orbit, six of which were intended to provide high-speed Internet access. Half of the six Internet satellites served the United States and Canada, but none served the other G7 nations:²⁰

- AMC 5 (North America)
- Eutelsat 115 West A (North America)
- AMC 4 (Continental U. S., Mexico, and northern South America).
- Arabsat 3A (Middle East)
- Asiasat 3S (South Asia)
- Africasat 1 (Africa and Asia)

With extensive deployment of telephone, cable, mobile and satellite, the U. S. was in a very strong position to develop a robust and diverse broadband marketplace as demand for high-speed Internet service began to grow.

iii. Policy Frameworks

The U. S. and Canada inherited two regulatory frameworks from the pre-broadband era: a common carriage framework for telephone networks and a contract carriage framework for cable TV networks. Thus, the formation of broadband policy in the U. S. in the 1990s was a debate over the merits and demerits of two very different but equally established frameworks that already applied to the two networks over which broadband service was supplied.²¹ Telephone service in these two countries was supplied by privately owned, highly regulated monopolies. The U. S.-Canada model – termed the “Pioneer Model” in this study – reserves subsidies for some R & D and rural network expenses and relies on private capital to finance the most advanced urban systems. The primary government role in these nations is to accelerate diffusion of advanced technologies to rural areas.

Europe and Japan inherited an entirely different framework, as government-owned monopolies in the process of privatization supplied telephone service and cable was rare. Consequently, the model developed for the privatization of the telephone network was reflexively applied to broadband without deep consideration of alternatives. In many respects, the framework used by the U. S. to complete the Bell System divestiture resembles the privatization model; Local Loop Unbundling (LLU) is a

common element. In Europe, subsidies are often used to inject advanced technologies into urban markets, but they are also used to fund rural systems.

In all G7 nations, regulatory models changed over time. The initial EU regulatory model was based on Thatcher-era U. K. mechanisms developed to privatize BT and on subsequent desires to use the BT network to leverage broadband competition. The common EU framework was “transposed” into national law in each member state. National Regulatory Authorities (NRA) then modified common policy to meet national goals. In North America and Japan, policy can be adapted to national goals continually without the laborious step of coordinating with a transnational and unresponsive body like the European Commission.

E. Progress

Initial starting points produce different effects at each stage of technical marketplace development. One obvious effect takes place in nations without cable: while they’re able to supply basic broadband in both urban and rural areas over telephone wire, the transition to NGA requires new cabling. Given that new cabling must be installed, it makes sense to skip coaxial and go to the pervasive stage with FTTH. This choice puts the nation in a better position to meet the challenge of ultra-high capacity networking than it might be if it had inherited a cable TV system.

Similarly, nations with poor telephone systems – such as Italy – are more highly motivated to adopt mobile phones than nations with higher-quality PSTNs.

For purposes of analysis, it’s reasonable to surmise that broadband progress undergoes three fundamental stages of development:

Stage One: Basic Broadband

- 1) Desktop computer is the standard networking device.
- 2) Baseline copper twisted pair for telephone service enables basic ADSL at capacities of 256 Kbps to 6 Mbps.
- 3) Baseline copper coaxial cable in combination with fiber optics enables DOCSIS cable modem service at capacities of 1 Mbps to 20 Mbps.
- 4) Wireless broadband is limited to Wi-Fi with less capacity than common wired networks.
- 5) Basic Content Delivery Networks appear to offload core networks.
- 6) Applications are limited to email, the Web, and simple Standard Definition video streaming

Stage Two: Advanced Broadband

- 1) Laptop computers become common networking devices.
- 2) Partial replacement of copper pair with fiber and use of Vectoring increases capacity to 40 Mbps or more for DSL.
- 3) Channel bonding increases cable capacity to the DOCSIS 3.0 level, 100 Mbps or more.
- 4) LTE enables mobile broadband to compete in speed and coverage with speeds in excess of 20 Mbps.
- 5) Wi-Fi outpaces wired broadband capacity.
- 6) Value-Added Content Delivery Networks optimize applications for varied devices.

- 7) Applications become more rich, encompassing immersive video conferencing, Ultra HD (4K) video, and large numbers of video streams.

Stage Three: Pervasive Broadband

- 1) Most end-user Internet connections are wireless.
- 2) Tablets, smartphones, sensors, and appliances are the most common networking devices.
- 3) Mobile networks reach hundreds of Mbps in fixed and mobile configurations.
- 4) Wired backhaul reaches gigabit capacities.
- 5) Cloud Computing is embedded in the basic Internet experience.
- 6) Applications encompass mobile virtual reality and augmented reality, large group video exchanges, hundreds of devices per home and thousands per business.

The elements of each stage in this progression are interdependent, with each reinforcing the role of the others and the combination creating the push to advance to the next level. We want to see developments in each stage that maximize social benefits within the stage and also create momentum toward the following stage.

F. Leadership

One common recipe for policy success comes from accurately predicting future trends and facilitating them, but this is harder than it appears to many. Technology forecasters are divided on the question of whether the future of networking will be predominately wired or wireless; in the technology community, there is a broad consensus that wireless will dominate, but in policy circles wired still commands many adherents.²²

This is an important question that plays out in many areas from spectrum policy to subsidy programs for wired networks. As the OECD data suggest, there has been a long history in network policy of regarding wired as the dominant modality and wireless as an afterthought. Many policy mavens still regard wireless as the red-haired stepchild of networking, even as smartphones and tablets have become the “first screen” for many and the only screen for some.²³

Australia’s ill-fated National Broadband Network is illustrative. That nation went whole-hog for a nationwide GPON FTTH network, only to encounter ballooning costs and ever-increasing buildout delays. This contributed to the ouster of a government and the recalibration of the plan toward a more modest multiple technology model. A side effect of the NBN was a large cash payment to former incumbent Telstra that was used to upgrade its mobile network. Arguably, Australia now has the world’s best LTE network thanks to a policy blunder that over-valued FTTH and under-valued mobile and dynamic competition.²⁴

One middle way position on the future of networking predicts increased penetration of fiber to businesses and neighborhoods alongside a fundamentally wireless edge; the current generation of college students already consists of a majority who have used computers since early childhood but have never connected an Ethernet cable. This appears to be a reasonable scenario that policy should drive toward, although we won’t know what the future holds until it arrives.

The ultimate conclusion is that the future is unknowable, so policy must allow rapid adaptation to user demands as they actually materialize. The “middle way” is to adopt

no set path at the outset; as Emerson said: “Do not go where the path may lead, go instead where there is no path and leave a trail.”

2. Broadband Coverage

The first policy question about broadband networks concerns the extent of network deployment or coverage; until there is a network, there is no need to concern ourselves with subscriptions, performance, prices, or benefits. In most of the G7, broadband coverage by services that permit basic utilization of the web is an accomplished task. In the U. S., NTIA reports 100 percent non-satellite broadband availability.²⁵ The questions that remain simply concern the details. It’s nevertheless instructive to see how we got where we are. The research arm of the Organisation for Economic Co-operation and Development (OECD) assembles the most useful historical data on broadband coverage.

A. Homes Passed by Basic Broadband Technologies

OECD data on homes passed by technology is still at least five years old; OECD data is therefore useful as a guide to broadband deployment in the Basic Broadband Stage and only in that stage.

i. Digital Subscriber Line (DSL)

OECD DSL deployment data does not distinguish types of DSL and has not been updated since 2009, but very little new DSL has been installed since then.

As expected, DSL coverage is most extensive in nations with small rural populations and little or no cable modem service.

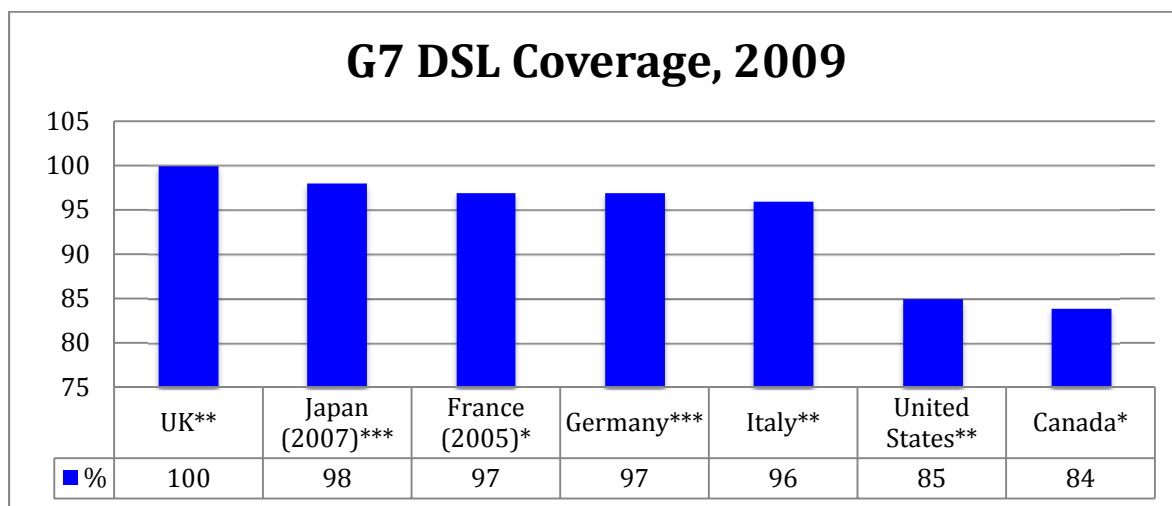


Figure 22: G7 DSL Coverage in 2009 (except as noted). Source: OECD

The numbers are also counted in different ways: by population, by household, and by number of lines: (*) Population, (**) Lines, (***) Households. DSL coverage is measured in various ways across the OECD.

ii. Cable Modem (DOCSIS)

OECD cable modem data are similarly dated and includes no entry for Japan, which is known to have extensive cable coverage. According to the Japan Cable Television Engineering Association (JCTEA), cable modem passed nearly half of Japanese homes by 2010. OECD and JCTEA cable deployment data is for all types of cable modem service, the Basic Stage.

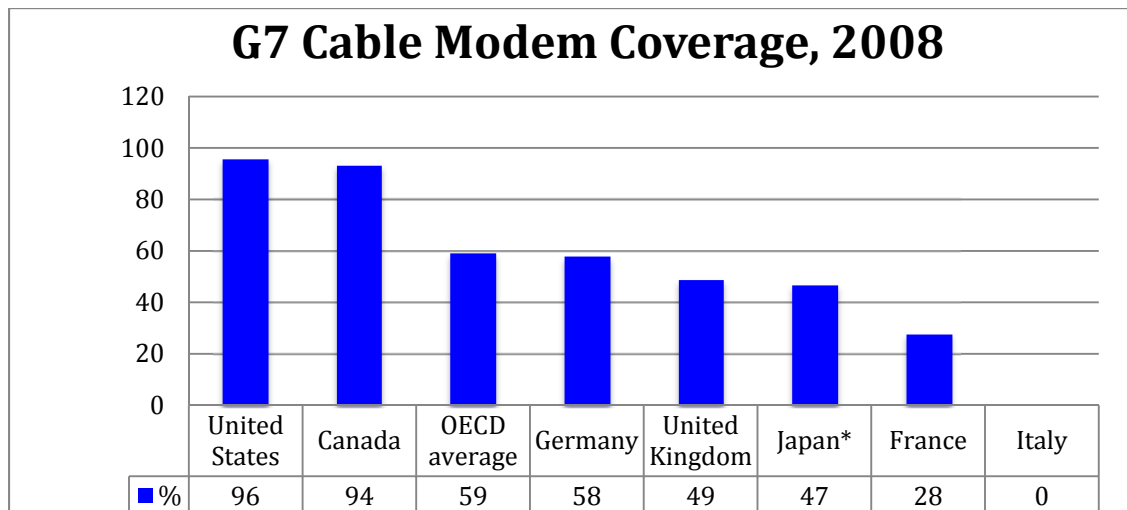


Figure 23: G7 Cable Modem Coverage in 2008. Source: OECD²⁶ and *JCTEA²⁷

iii. Fiber Optic Broadband

OECD fiber coverage is only accurate up to 2009. Extensive fiber deployment in the U. S. has more than doubled this figure today according to government reports.

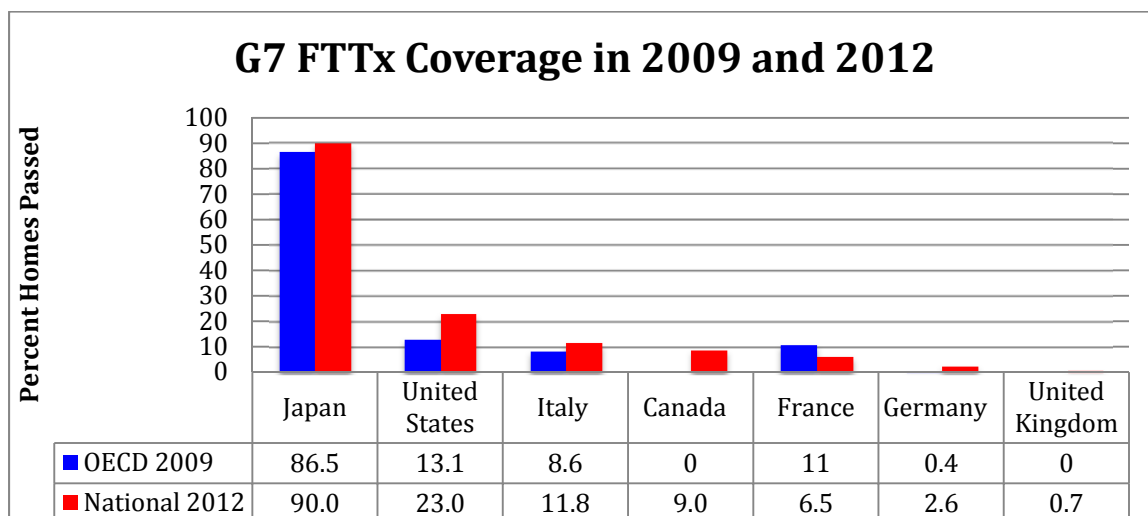


Figure 24: G7 Fiber Coverage in 2009 and 2012. Source: OECD²⁸, NTIA²⁹, EC³⁰, CRTC³¹.

Within the EU, there is considerable inconsistency in the reporting of VDSL Fiber-to-the-Cabinet (FTTC) and Fiber-to-the-Home or -Basement, FTTH/B. The term "FTTx" includes both modes of fiber. VDSL is actually a hybrid of copper and fiber, just as cable modem is a hybrid of coaxial cable and fiber, but FTTx excludes cable modem.

iv. 3G Mobile Broadband

OECD's mobile coverage data is similarly dated, ending in 2009 with 3G wireless, a technology best regarded as Basic Broadband since its top speeds are less than 4 Mbps.

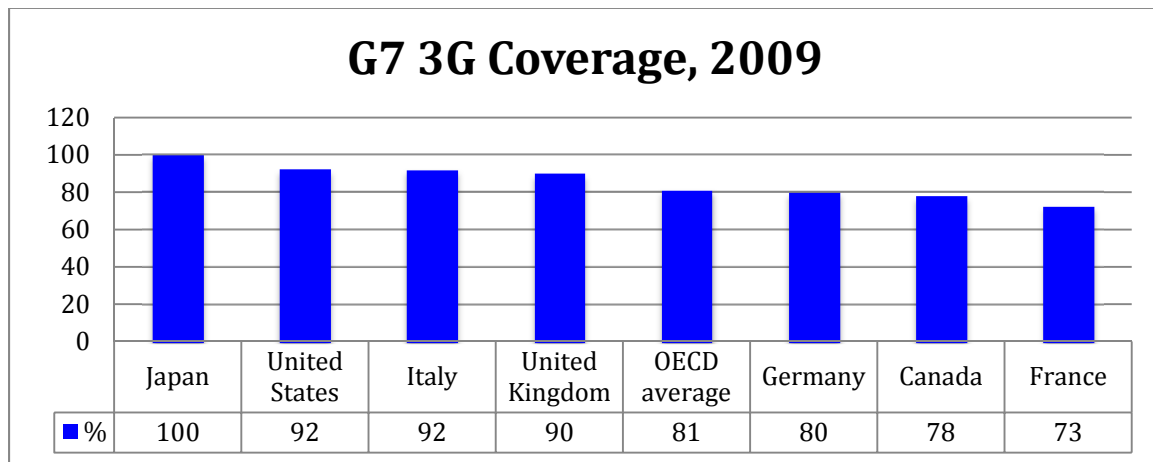


Figure 25: G7 3G Mobile Coverage in 2009. Source: OECD³²

B. Number of Providers in the Basic Broadband Stage

Bimodal coverage can be calculated on the basis of the lesser of the two largest coverage values (typically DSL and cable, but DSL and fiber in the case of Japan).

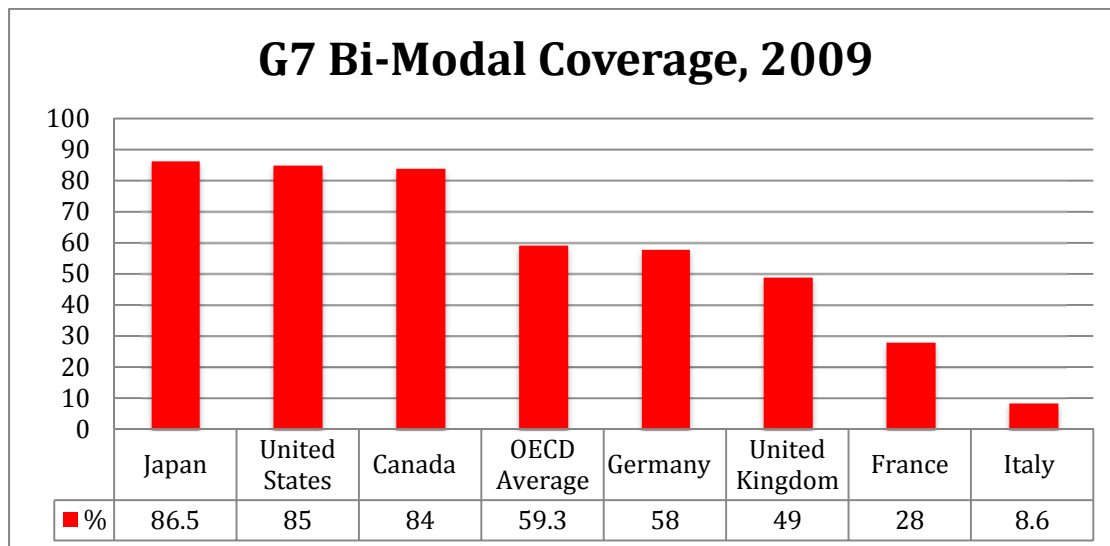


Figure 26: G7 Bi-Modal Competition in 2009. Source: OECD³³

We can calculate a tri-modal coverage table from using the minimum of DSL, cable, and 3G for most countries and DSL, fiber, and 3G for Japan.

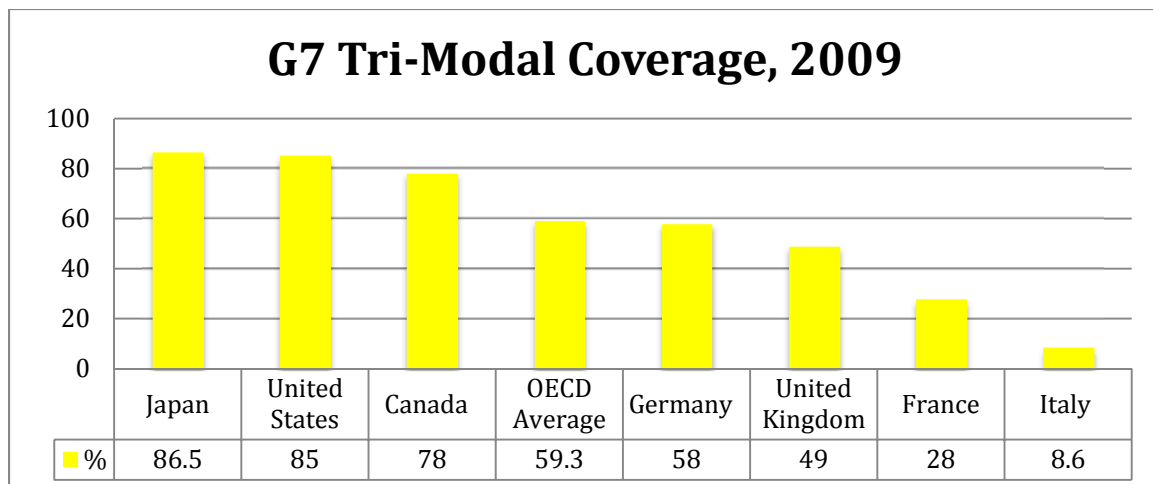


Figure 27: G7 Tri-Modal Competition in 2009. Source: OECD³⁴

The ranking order is the same as for the bi-modal table, but the gap between the U.S. and Canada is wider owing to lower 3G coverage than DSL coverage in Canada.

C. Number of Providers in the U. S. Presently

The National Broadband Map calculates multi-modal competition on the basis of the number of providers capable of supplying broadband by its definition (10 Mbps download) both by technology and independent of technology. It includes business Competitive Local Exchange Carriers (CLECs) in its provider count and thus overstates residential competition.

These measures have somewhat limited application as they don't factor the effects of usage limits on some wireless accounts that constrain their usefulness for such applications as video streaming that comprise two percent of Internet usage by time. The National Broadband Map data suggest that rural wireless broadband coverage is somewhat limited, but this is changing.

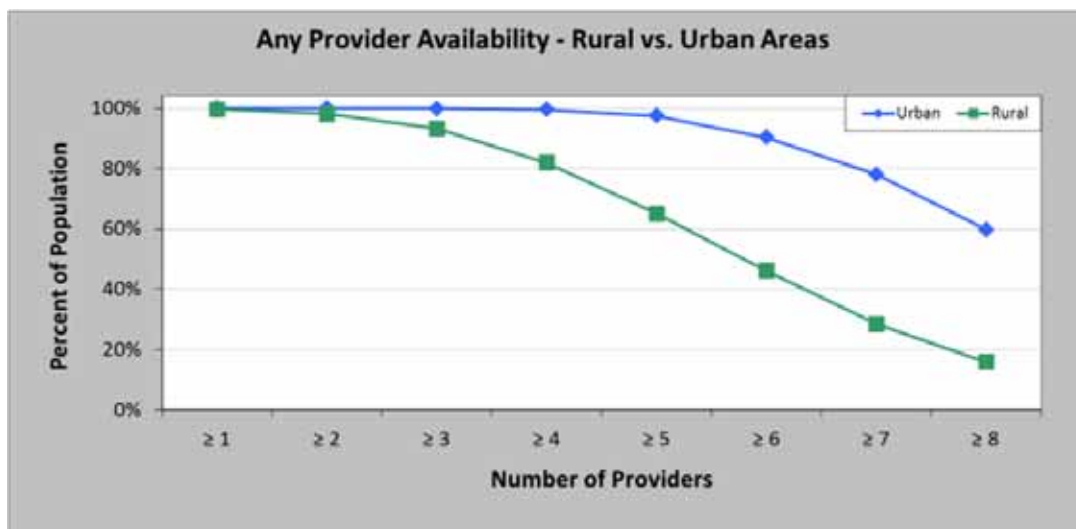


Figure 28: U. S. Urban vs. Rural Broadband Competition. Source: NTIA³⁵.

By NTIA's definition, 100 percent of urban America has access to at least four providers of broadband service (including CLECs); 100 percent of rural America has access to at least one; and 95 percent of rural America has access to at least two.³⁶ These options include wireless at the requisite speed, but not satellite.

The state of broadband competition has thus improved dramatically for business users over its condition when OECD stopped collecting coverage data in 2009. Surprisingly, the National Broadband Map finds that many Americans have three or more choices of wired broadband providers; more than 65 percent in urban areas and nearly 20 percent in rural areas; this is a CLEC effect.³⁷

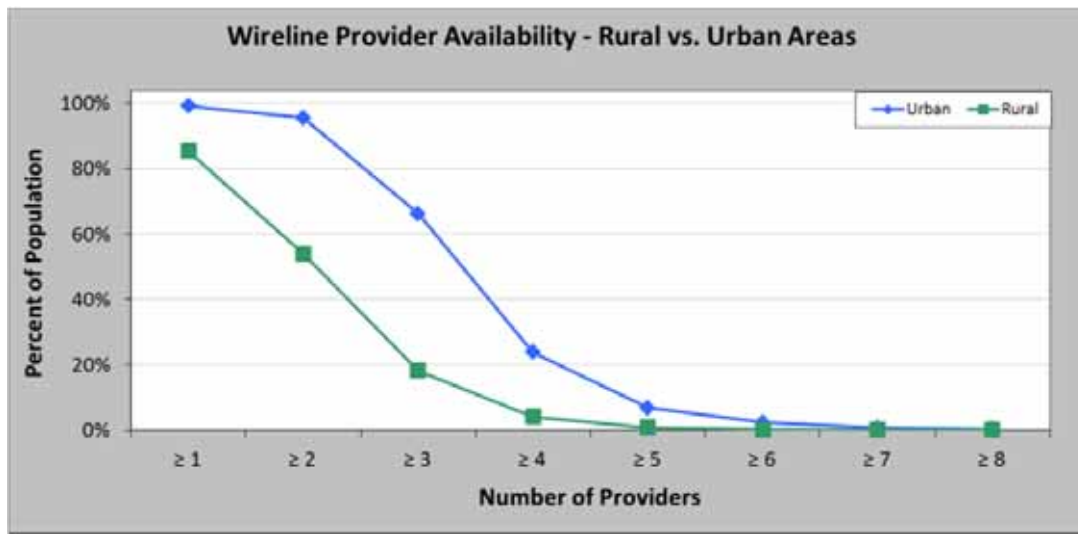


Figure 29: U. S. access to multiple wired broadband choices. Source: NTIA.³⁸

D. Deployment of Advanced Broadband in the G7

Advanced Broadband is termed "Next Generation Access" (NGA) in international policy discourse. This form of broadband is generally defined as any broadband technology with a gross download capacity of 25 - 30 Mbps or higher, whether shared or unshared. Common NGA technologies are:

- VDSL (Hybrid fiber/copper DSL, vectored, short distance, and/or pair-bonded, including VDSL2+)
- DOCSIS 3.x at 30 Mbps (shared) and above
- xPON or Optical Ethernet at any speed
- 3.9G/4G/LTE mobile broadband at 25 Mbps and above

OECD has declined to collect data on leading-edge networks, so we turn to the regional and national government authorities for information on deployments in the G7 as of the end of 2012.

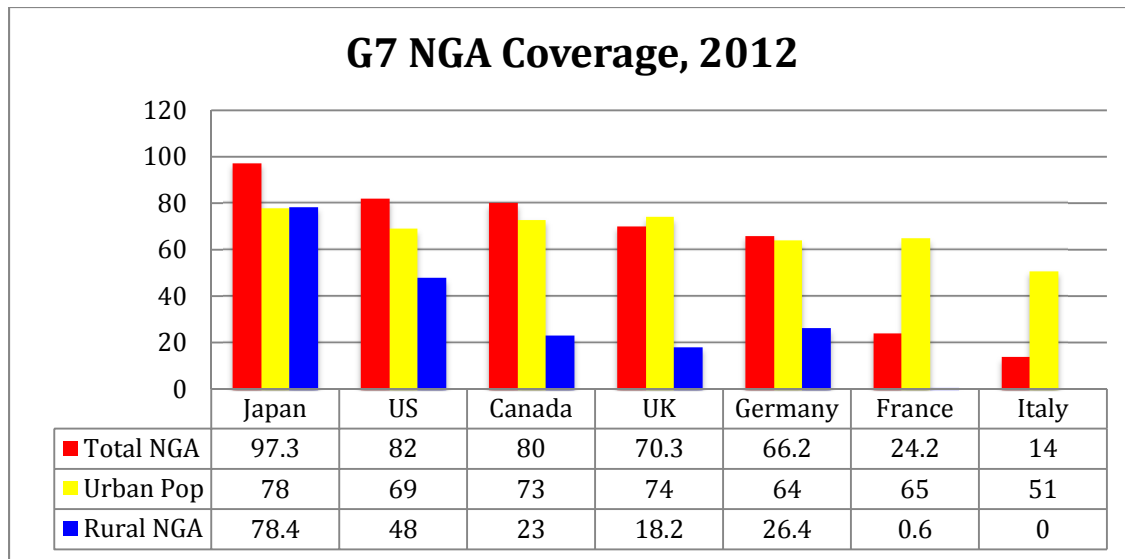


Figure 30: G7 NGA coverage and urban population 2012. Sources: EC³⁹, NTIA⁴⁰, MIC⁴¹, CRTC⁴², World Bank⁴³.

Japan is the leader in total NGA coverage thanks to its ten-year commitment to a pervasive FTTH network based on an early version of the xPON technology used by Verizon and Google, but the U. S. and Canada are close behind on the strength of their diverse broadband strategy.

NTIA's National Broadband Map details the gap between urban and rural NGA coverage, an area of immediate government concern as long as rural broadband markets remain difficult to serve.

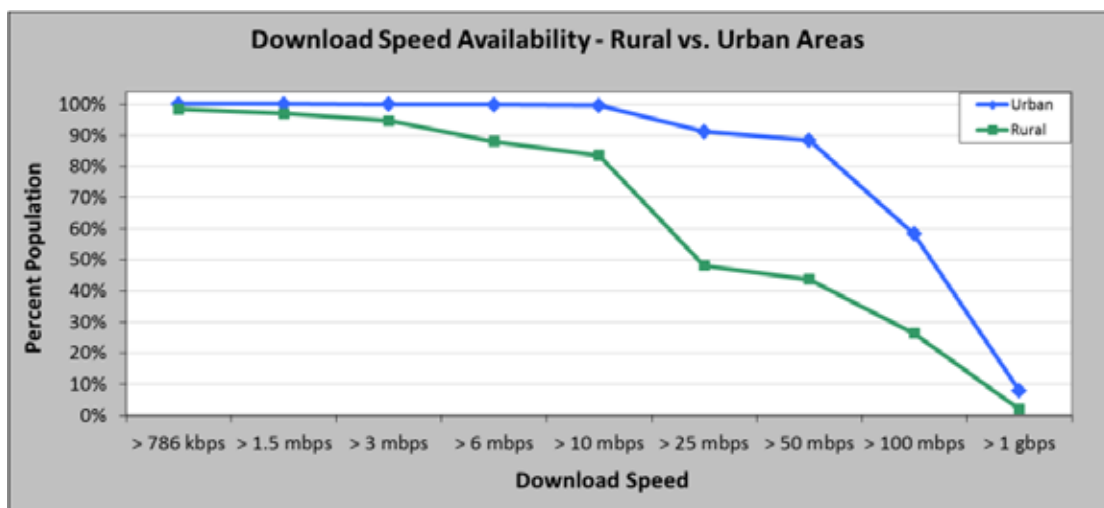


Figure 31: U. S. Urban and Rural Broadband by Capacity, 2012. Source: NTIA.⁴⁴

i. Advanced DSL

Advanced DSL includes VDSL, VDSL2, VDSL2+, and Vectored DSL, technologies that are commonly lumped together as "VDSL". They primarily differ from baseline ADSL in terms of capacity: typical capacities for ADSL are less than 12 Mbps, while VDSL typically provides 20 - 80 Mbps; the highest speeds being enabled by Vectoring. A more

advanced form of DSL is G.Fast, with theoretical capacities up to 1 Gbps under ideal conditions (copper loops less than 500 feet).

The capacity of all forms of DSL is to a great extent a function of the length of the copper wire or “loop” connecting customer premise to the DSL access multiplexor (DSLAM). ADSL loops are commonly 5 to 10 thousand feet, while VDSL loops are less than 3,000 feet long and the G.Fast loop is hundreds of feet. VDSL achieves higher capacity than ADSL through a combination of techniques:

- 1) Shorter copper loops;
- 2) Advanced signal processing; and
- 3) Doubling copper wire pairs (“pair bonding”)

In many instances, networks classified as FTTP are actually combinations of Fiber to the Basement (FTTB) in high-rise buildings and VDSL or copper Ethernet from the basement to the apartment. The European Commission classifies VDSL as fiber (FTTx) in many publications.⁴⁵

A recent study by the CTIC credits VDSL with increasing broadband capacity in many European nations without aggravating the “Digital Divide”.⁴⁶ It recommends emphasis on cable and VDSL for egalitarian reasons.

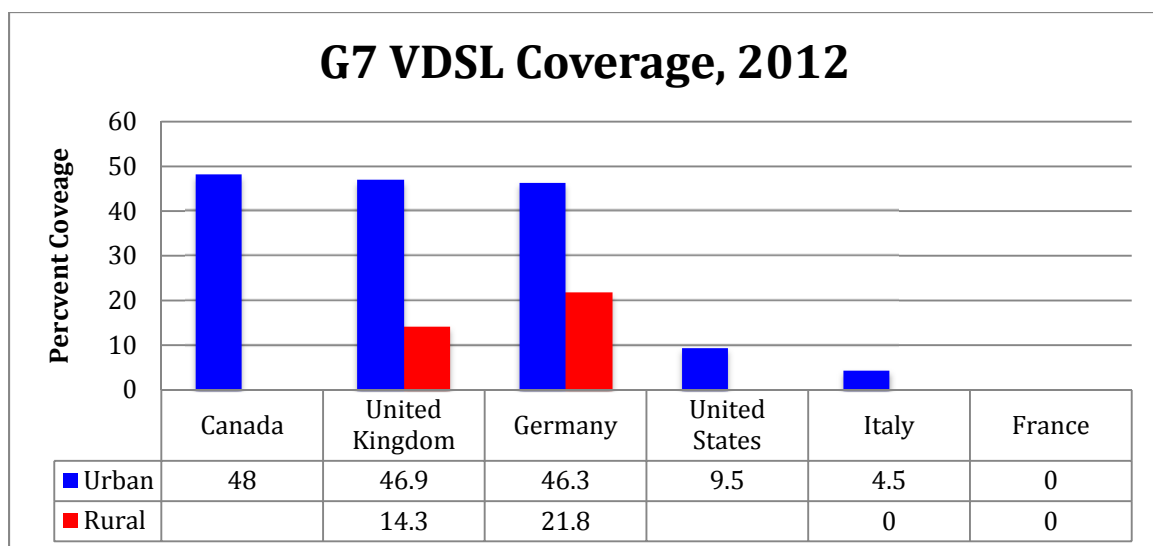


Figure 32: G7 VDSL Coverage 2012. Source: EC⁴⁷, NTIA⁴⁸, CRTC⁴⁹

This chart appears to understate VDSL availability in the U. S.; consultants such as **Leichtman** Research say nearly a million Americans convert from ADSL to VDSL every quarter.

ii. DOCSIS 3.0

The third generation of cable modem service, DOCSIS 3, enables users to share standard capacity of 160 Mbps as well as additional configurations up to 1 Gbps or more. Service providers sell services in capacity tiers, typically at 20, 30, 50, and 100 Mbps. As many as 100 – 200 households can share a 160 Mbps DOCSIS 3 without significant degradation, but service providers can also limit sharing by “node splits” if they wish. DOCSIS 3 is the most common form of NGA networking in the world today.

Not surprisingly, DOCSIS 3 is most widely used in the nations that were already wired for cable before broadband services were introduced, and its presence in a market tends to spur deployment of competitive facilities such as VDSL, FTTx, and LTE. DOCSIS 3 is also attractive in nations that regulate it more lightly than the twisted-pair telephone wire plant is regulated; U. S. investor Liberty Global is on a buying spree for European cable companies to exploit this advantage.⁵⁰

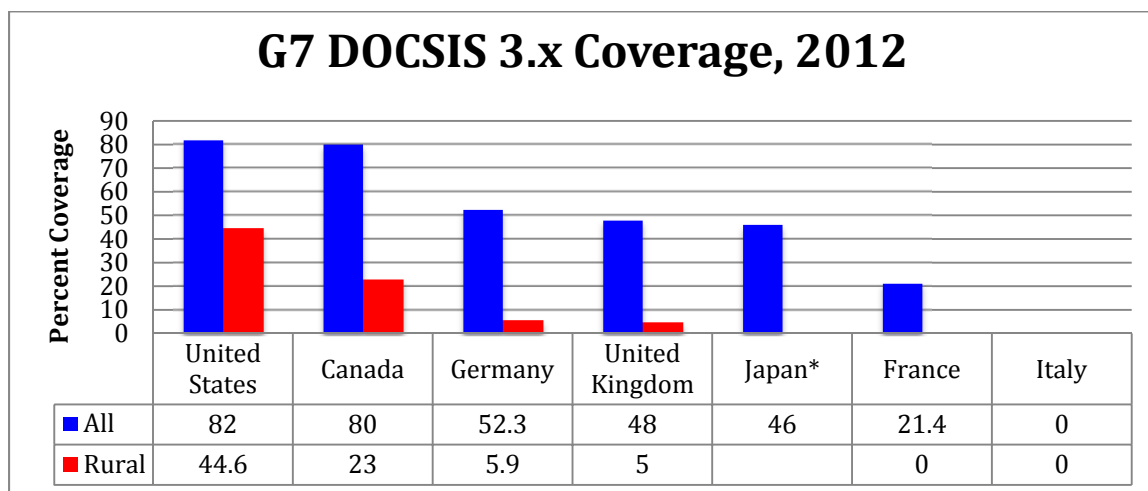


Figure 33: G7 DOCSIS 3.x Coverage 2012. Source: EC⁵¹, NTIA⁵², CRTC⁵³, JCTEA⁵⁴. Japan from 2010, Canada estimated.

iii. Fiber to the Home

Fiber to the Home and Fiber to the Basement are properly grouped together as FTTH/B, but VDSL in combination with Fiber to the Cabinet is considered in its own category, FTTC. The EU and NTIA/FCC provide coverage data for FTTx in both urban and rural settings, but data for Canada is generally lacking and data for Japan is sparse because there's no reason to deploy VDSL in a nation already equipped with FTTH.

Canada's data is inferred from the FTTH Council's 2011 G20 scorecard. As it measured adoption, the score has simply been tripled. Japan reports NGA without distinguishing technology, but its FTTH/B score is virtually 100 percent. While FTTH/B can offer extremely high capacities - into the multiple Gbps - real implementations rarely offer more capacity than DOCSIS.

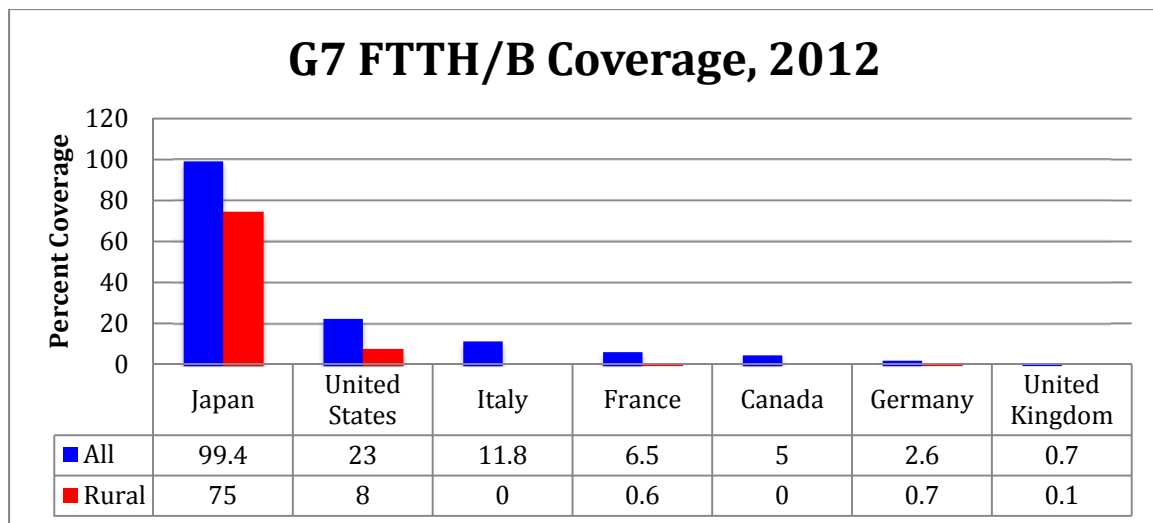


Figure 34: G7 FTTH Coverage, 2012. Source: EC⁵⁵, NTIA⁵⁶, MIC⁵⁷, FTTH Council. Canada estimate

iv. 4G/LTE

The U. S. was the first nation to deploy LTE at scale, beginning with the MetroPCS and Verizon deployments in 2010.⁵⁸ American firms were motivated to move to LTE because of CDMA's bandwidth limitations, but they were also allowed to upgrade because their spectrum was not burdened by a technology mandate as was the case in the European Union. LTE spectrum was also made available in the U. S. by the first DTV spectrum auction in 2008.⁵⁹

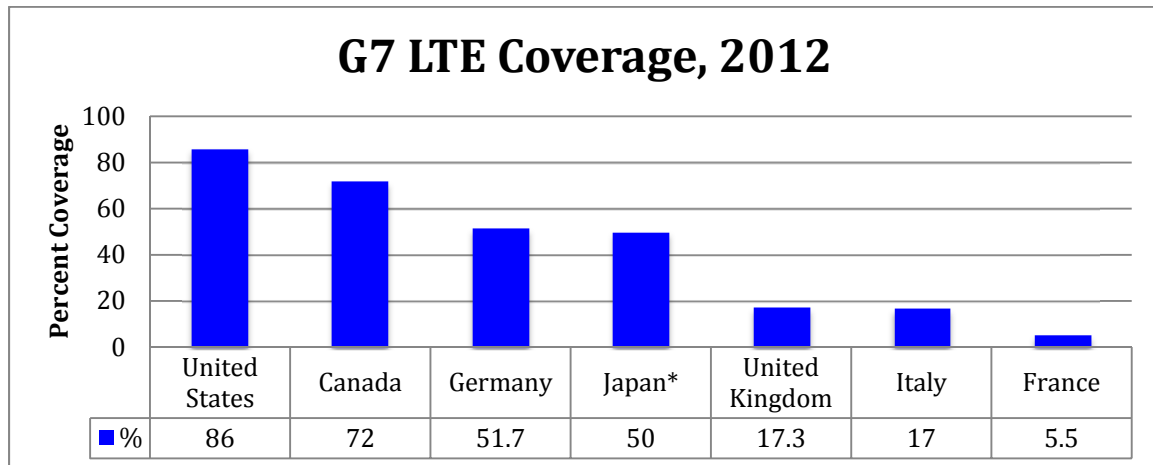


Figure 35: LTE Coverage in 2012. Source: EC⁶⁰, NTIA⁶¹, CRTC⁶². *Japan estimated.

E. GigaMania: 1000 Mbps Networking

Gigabit fiber connections are now relatively common in Japan and among Asian Tigers, and are beginning to emerge in the Nordic countries that have long held a fascination for ultra-fast Internet connections. NTIA reports that ten percent of urban American homes are passed by gigabit services, and carriers such as Verizon, Comcast, Century Link, and AT&T are in position to offer gigabit services as and when demand develops by upgrading their electronics; this isn't cheap, but it's less expensive than upgrading cable as well.⁶³

i. Gigabit Projects

AT&T announced an initiative in April that would provide “GigaPower” connections in as many as 100 cities:

AT&T today announced a major initiative to expand its ultra-fast fiber network to up to 100 candidate cities and municipalities nationwide, including 21 new major metropolitan areas. The fiber network will deliver AT&T U-verse® with GigaPowerSM service, which can deliver broadband speeds up to 1 Gigabit per second and AT&T’s most advanced TV services, to consumers and businesses.⁶⁴

CenturyLink now offers gigabit services in 16 cities:

[CenturyLink, Inc.](#) (NYSE: CTL) today announced that symmetrical broadband speeds up to 1 gigabit per second (Gbps) are available now to residential and business customers in select locations in [16 cities](#) through its ultra-fast fiber network. Thousands of customers can begin enjoying the benefits of gigabit speeds and hundreds of thousands of residential and business customers will also have access to these advanced fiber services within the next 12 months.⁶⁵

Comcast and other cable operators are quietly replacing coaxial cable with fiber in selected markets:

When customers in select parts of Comcast’s Northeast and Southern markets ask for the company’s fastest Internet speed of 505 megabits-per-second, the cable operator lays a fiber line to the customer’s home with capacity to offer the higher speed.⁶⁶

Verizon’s FiOS service is already capable of providing gigabit network services to 18 million homes, and despite news that FiOS deployment has completed, the firm has a FTTH deployment plan that extends to 2019.⁶⁷

Consequently, it’s reasonable to believe that gigabit networks will be common across America’s urban areas as soon as competition and demand call for them. There’s certainly a great deal of activity taking place well ahead of demand; the Gig.U third annual report chronicles a number of gigabit projects with various funding mechanisms.⁶⁸

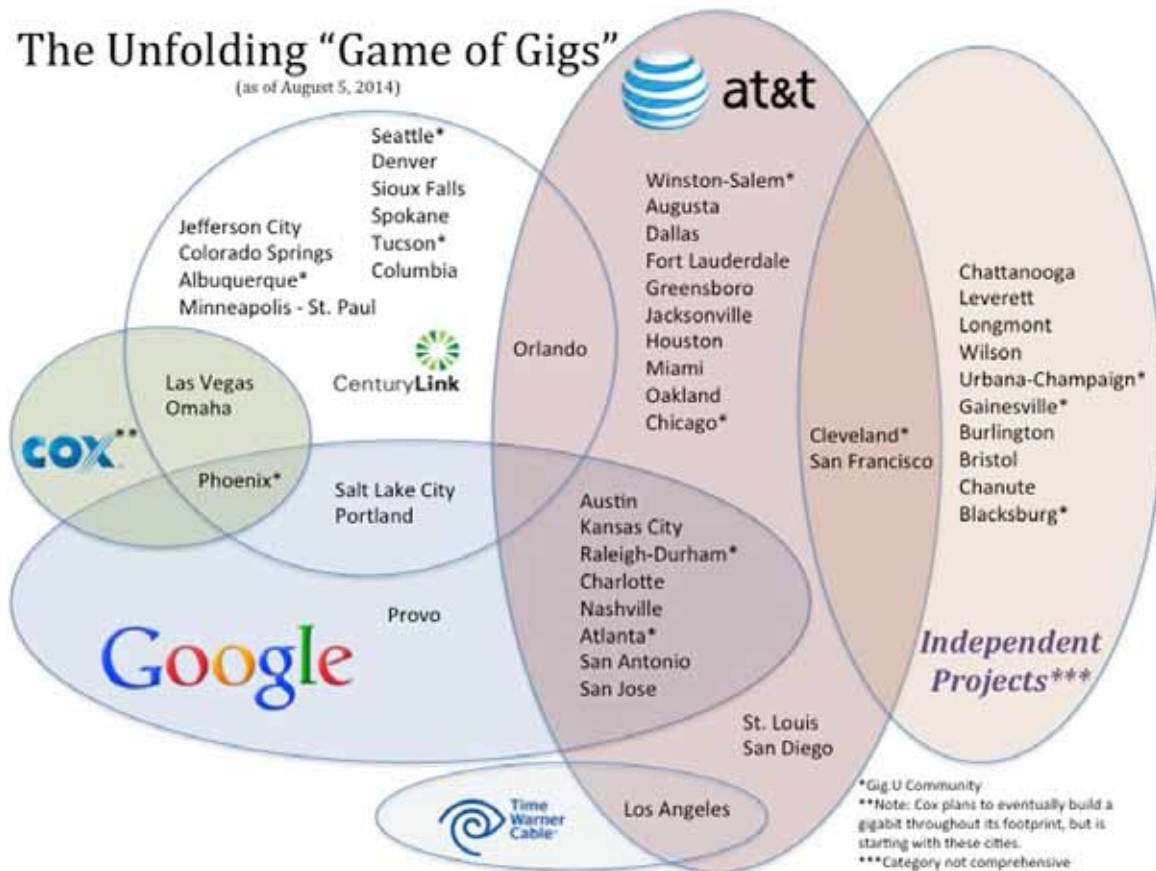


Figure 36: U. S. gigabit network deployments. Source: Gig.U.

Commercial gigabit connections have been common in major American cities since the late 1990s.⁶⁹

ii. Gigabit Utility

For gigabit networks to capture the imagination of the public, they will need to enable new applications. These applications would need to be exciting, capable of performing well with gigabit capacities, but impractical at today's common 40 - 100 Mbps capacities. Such applications do not currently exist.

It's not difficult to imagine gigabit applications, and indeed the advent of gigabit LANs and campus networks in the late 90s stimulated attempts to visualize them. Systems of instantaneous browsing, holographic conferencing, virtual reality (the Star Trek Holodeck), advanced medical imaging, and "Big Data" transfers fill the bill). *Cluetrain Manifesto* co-author David Weinberg imagines gigabit networks supporting social surveillance:

If we had truly high-speed, high-capacity Internet access, protesters in Ferguson might have each worn a GoPro video camera, or even just all pressed "Record" on their smartphones, and those of us not in Ferguson could have dialed among them to see what's happening. In fact, it's pretty likely someone would have written an app that treats co-located video streams as a single source to be made sense of, giving us fish-eye, fly-eye perspectives anywhere we want to focus: a panopticon for social good.⁷⁰

But we haven't seen this happening in areas that have gigabit networks. Regardless of future applications, today's video conferencing, remote learning, video streaming, cloud backup, and home security applications don't require gigabit networks; these applications are perfectly viable on today's 40 – 100 Mbps networks.

Some argue that despite gigabit networks' lack of present utility it's nevertheless important to deploy them today in order to nurture the applications of tomorrow. "If you build the networks, the applications will come" is the mantra, and there could be some truth in it. Some firms are extending gigabit networks to residences today, so it should be possible to see applications appear shortly if the mantra is correct. The U. S. government estimates that 10.5 percent of urban American homes have access to gigabit networks today.⁷¹

F. Gross Fiber Deployment

Prior to 2011, the year 2000 had featured the largest annual deployment of fiber optic cable in American history. Throughout the '00s, there was a glut of dark fiber in the U. S. thanks to the ambitions of firms such as Global Crossing who tried – and failed – to cash in on the "fiber bubble". The glut has been exhausted and the U. S. is installing fiber optic cable at the rate of 20 million miles a year, greater than the rate for all of Continental Europe, but behind the rate for China with its large land mass, large population, and lower starting point.⁷²

3. Broadband Subscription Rates

Subscription rates for broadband are notoriously difficult to measure in a timely fashion on the global scale because of peculiarities in reporting and delays in publishing by OECD's research department. OECD reports subscriptions on a per-100-population basis, but U. S. households are larger than those in most OECD nations, so U. S. subscription rates tend to be understated in international measurements.

A. Subscription Rate

The most recent data from OECD says that 71.1 percent of Americans subscribe to a wired broadband service, roughly the same figure reported by the Pew Internet and American Life Project.⁷³ This figure reflects less interest in the wired Internet in the U. S. than in some other countries. Interest in the Internet is largely a function of age, literacy, and income. While the U. S. has a smaller elderly population in relation to the working age population than most other G7 nations, it has greater income disparity.⁷⁴

There is also reason to believe that interest in the Internet is highest in nations with long winters where indoor entertainment is more highly valued than it is in the U. S.; Scandinavian nations show high interest in the Internet, for example.

Wired-only subscription data also hide the effects that greater smartphone penetration has on Internet use by Americans who rely on wireless networks. In addition to the ~70 percent of Americans who access the Internet via wired connections, 16-17 percent access it exclusively from mobile devices.⁷⁵

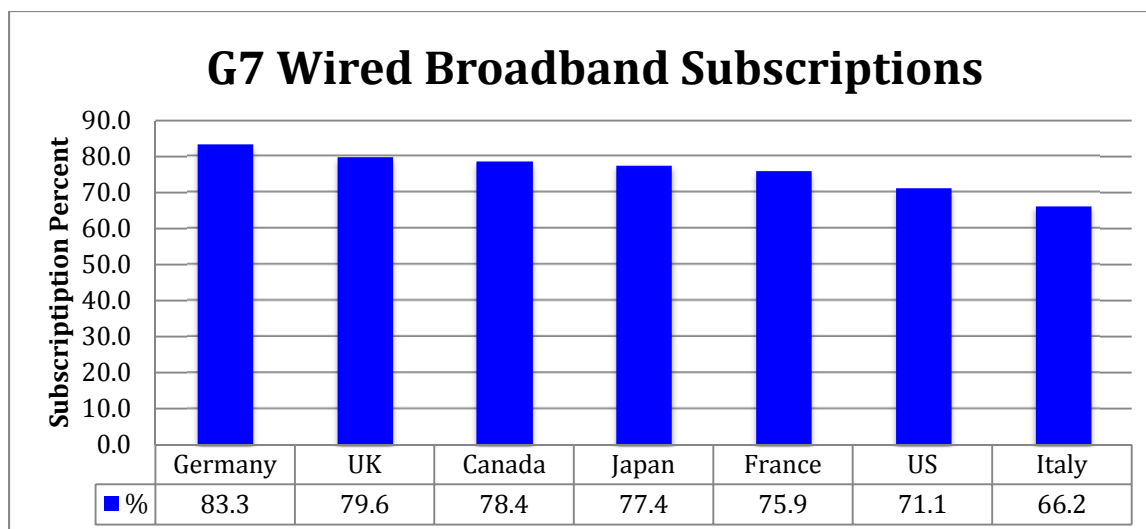


Figure 37: G7 Wired Broadband Subscription Rate. Source: OECD.⁷⁶

B. Subscription Rate by Technology

While most of the G7 accesses the Internet through DSL facilities, most Americans use cable modem services with higher speeds. Japan is the only G7 nation in which FTTH/B is the predominant form of Internet access, and this shows in that nation's performance measurements (other than Ookla Speedtest, which ranks Japan fifth in average download speed.) OECD ranks the U. K. higher than the U. S. on fiber subscriptions by classifying VDSL as a fiber technology rather than the more advanced form of DSL that it actually is; much of America's fiber is Verizon FiOS, a technology that takes fiber all the way to the residence. Most fiber connections in France, Germany, and Italy are legitimate FTTH, but they are very scarce.

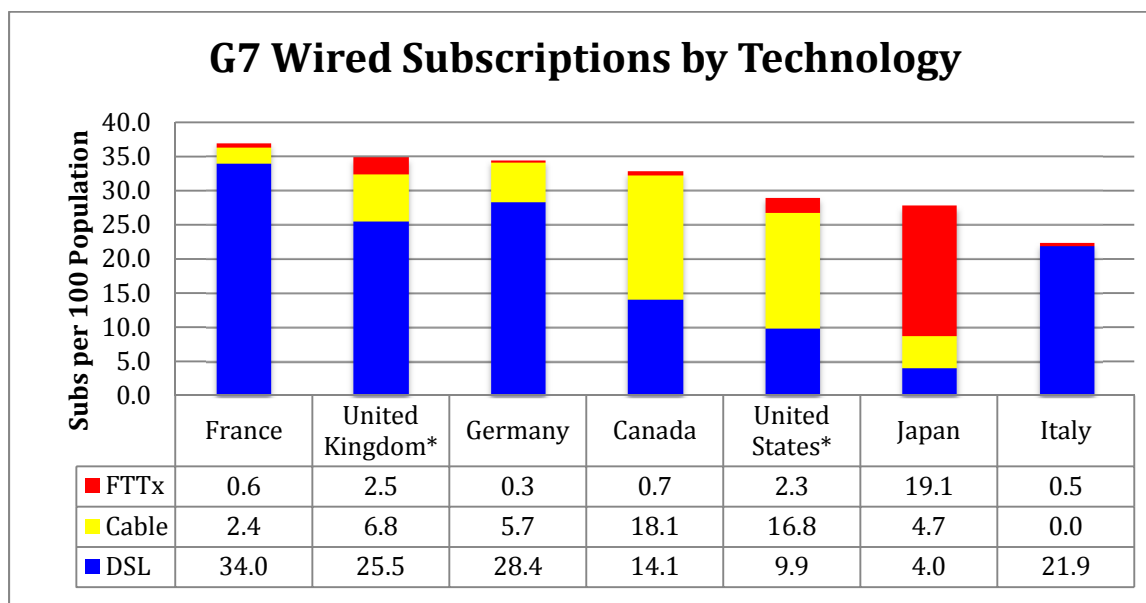


Figure 38: Wired Broadband Subscription Rate by Population and Technology, 2013. Source: OECD.⁷⁷
 *UK and US estimated by OECD.

As a percentage of all wired connections, Japan has the highest fiber preference at 68.5 percent, reflecting the nearly pervasive character of NTT's FTTH/B buildout. This buildout has proved beneficial to mobile operators who are often able to obtain inexpensive dark fiber from NTT to provide tower backhaul.

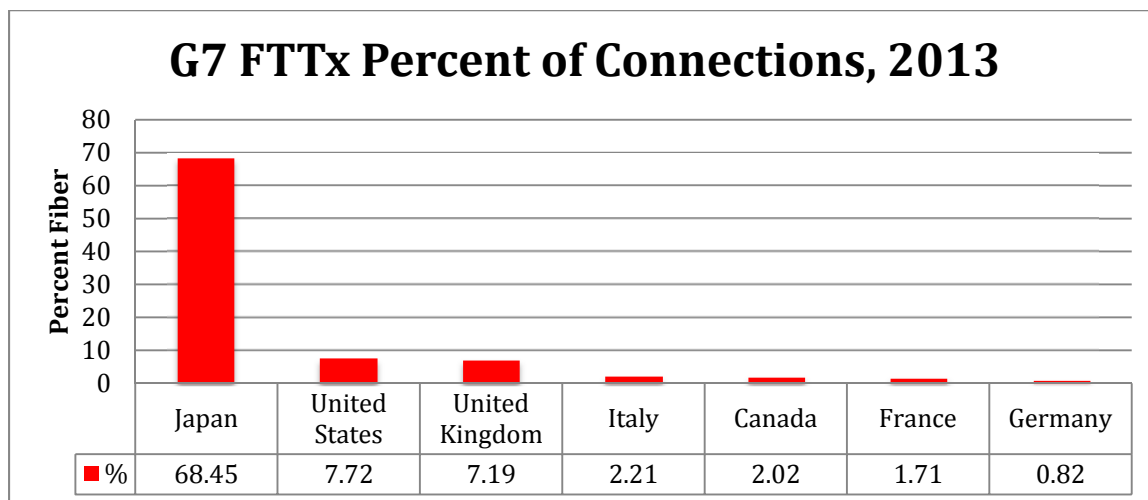


Figure 39: Fiber Subscriptions as Percent of All Broadband Subscriptions. Source: OECD.⁷⁸

One of the issues that bedevils broadband providers considering deploying fiber is the take rate, the percentage of potential customer who choose to switch to fiber from their previous plan or who subscribe to broadband for the first time. Carriers consider take rates proprietary information, so analysis is difficult.

Some analysts estimate a 40 percent take rate for FiOS, and even higher levels for Google Fiber, a network that relies on the Verizon-developed xPON technology. Other estimates are as low as 25 percent, the OECD figure. It's likely that the FiOS take rate is 30-35 percent, short of the 40 percent rate that Verizon anticipated. Google refuses to disclose take rates for its Kansas network, and take rates for municipal fiber networks tend to cluster at the most economical tiers.

The pattern of consumer indifference to extremely fast network services is international; Hong Kong Broadband Network Limited was not successful at attracting users to its fiber service until it offered promotional prices lower than DSL prices for users who recruited a friend. The HK \$13 promotional price it offered sent ripples through the local market, but they were short lived; shortly after the promotion ended, carriers went back to renting Wi-Fi routers for HK \$13/month over and above the price of broadband connections.⁷⁹

The issue with fiber take rates reflects the gap between consumer preferences and the desires of fiber fanatics; surveys often show consumers completely unaware of basic broadband service parameters such as upload and download speeds.⁸⁰ Increased activity in the fiber space reflects growing consumer interest in higher broadband quality.

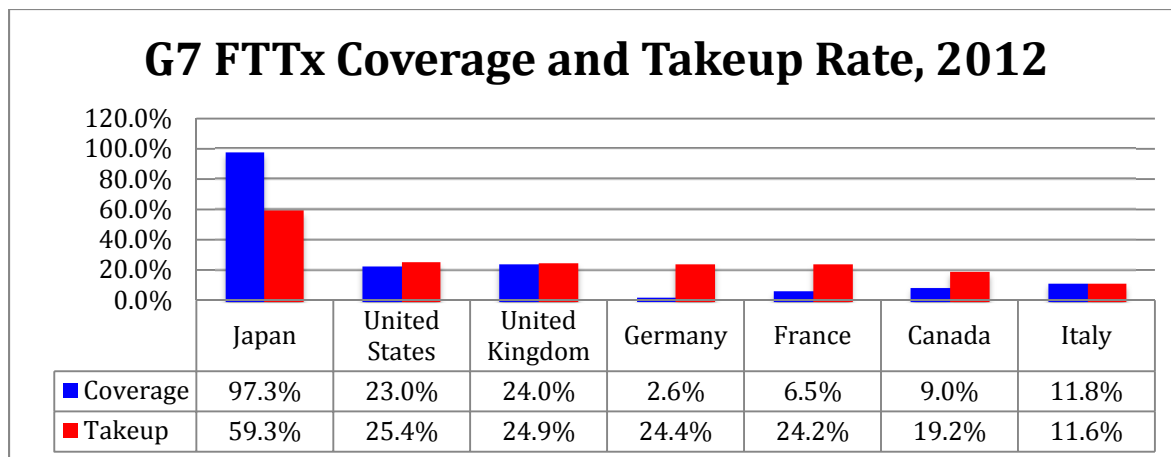


Figure 40: G7 FTTx Coverage and Takeup. Source: OECD⁸¹, MIC, World Bank⁸², NTIA⁸³, NationBuilder⁸⁴, EC⁸⁵. Note: Take-up rate calculated on the basis of total FTTx subscriptions divided by total households with FTTx coverage. UK figures include VDSL.

C. Wireless Subscription Rate

Pew also reports additional usage beyond those who use wired connections: "As of January 2014, 87 percent of American adults use the internet."⁸⁶ Many Americans use the Internet from mobile devices or at work or school, so it may no longer be reasonable to measure subscription rates on strictly wired networks. Bank of America/Merrill Lynch's Wireless Matrix shows that smartphone adoption has already reached 50 in the U. S. and U. K., and has reached significant mass in the rest of the G7.

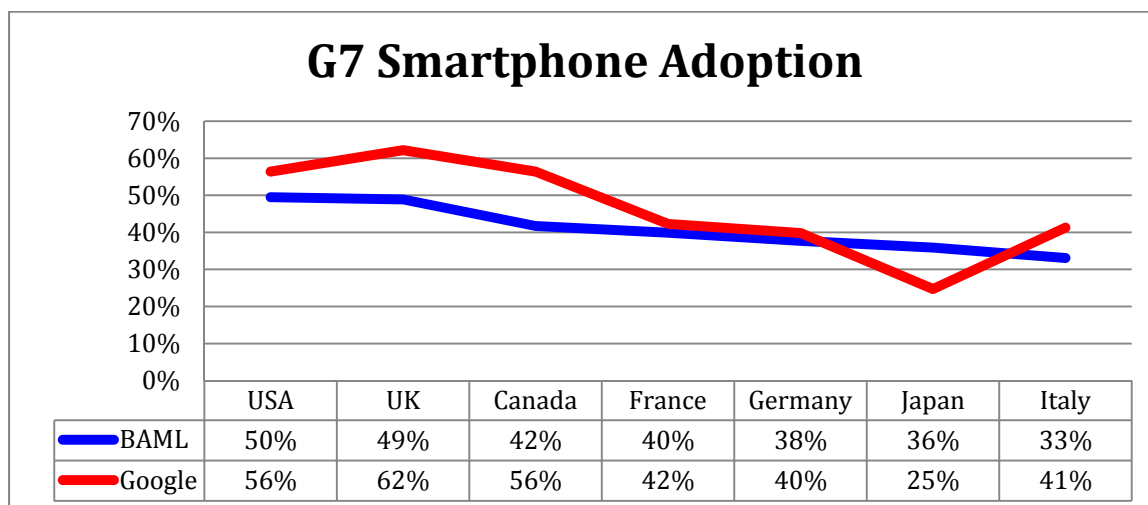


Figure 41: G7 Smartphone Adoption. Source: BAML Wireless Matrix⁸⁷ and Mobile Planet by Google.

Other sources are generally similar to Wireless Matrix with respect to smartphone adoption but show significant differences in some details, especially with respect to Japan. Mobile Planet by Google shows very low smartphone adoption in Japan, which is very hard to reconcile with estimates of mobile data usage. Cisco estimates that national mobile data usage is heaviest in Japan; 50 percent higher than the U. S. on a population-adjusted basis. Consequently, the external evidence suggests the BAML

estimate is more accurate. Pew Research estimates 56 percent smartphone adoption by U. S. adults, in line with Google's estimate.⁸⁸

OECD shows that most of the growth in broadband subscriptions in the G7 now takes place on mobile networks. In the U. S., mobile broadband subscriptions were up 13.1 percent in 2013, while wired subscriptions were only up 3.7 percent.

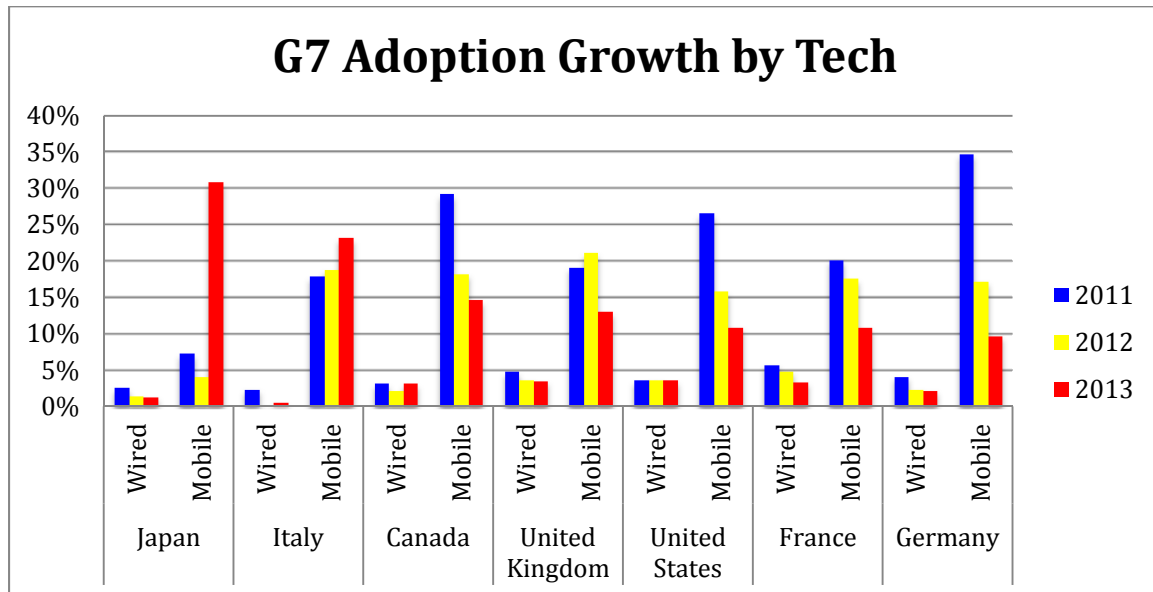


Figure 42: G7 Broadband Adoption Growth by Tech. Source: OECD.

The gap between mobile and wired growth rates is even more dramatic in Italy and Japan, where wired growth rates are less than two percent but mobile growth rates are 23 and 31 percent respectively.

		2010	2011	2012	2013
Japan	Wired	7.5 percent	2.7 percent	1.5 percent	1.4 percent
	Mobile	3.2 percent	7.4 percent	4.2 percent	30.9 percent
Italy	Wired	7.8 percent	2.4 percent	0.1 percent	0.6 percent
	Mobile	94.8 percent	17.9 percent	18.8 percent	23.2 percent
Canada	Wired	3.8 percent	3.3 percent	2.3 percent	3.3 percent
	Mobile	32.0 percent	29.2 percent	18.3 percent	14.7 percent
United Kingdom	Wired	6.0 percent	4.9 percent	3.7 percent	3.6 percent
	Mobile	44.7 percent	19.2 percent	21.2 percent	13.1 percent
United States	Wired	4.8 percent	3.7 percent	3.7 percent	3.7 percent
	Mobile	32.1 percent	26.6 percent	15.8 percent	11.0 percent
France	Wired	6.9 percent	5.8 percent	4.9 percent	3.4 percent
	Mobile	31.3 percent	20.2 percent	17.6 percent	10.9 percent
Germany	Wired	4.8 percent	4.2 percent	2.5 percent	2.3 percent
	Mobile	4.2 percent	2.3 percent	2.3 percent	2.3 percent

Mobile	50742.1 percent	34.7 percent	17.2 percent	9.8 percent
--------	-----------------	--------------	--------------	-------------

Figure 43: G7 Broadband Adoption Growth by Tech, Details. Source: OECD.

Mobile broadband subscription growth in Japan, Italy, and some other countries reflects a new kind of cord cutting, where young people are dropping wired broadband subscriptions in favor of advanced mobile broadband. This is an especially strong trend in East Asia, where wired networks are extremely fast but mobile networks are fast enough to meet a wide range of consumer needs. Informa analyst Tony Brown explains the dynamics:

Although the fact remains that wireless networks - even the greatly hyped newcomer LTE - can't carry the weight of demand for bandwidth from subscribers, there is now serious evidence emerging that the arrival of high-speed LTE networks coupled with the Smartphone and Tablet boom is creating serious problems for FTTH operators in some markets.

The best example of this is coming from Japan where fixed-broadband giants NTT East and NTT West have been forced to slash their FTTH prices for new subscribers by an eye-watering 34 percent from ¥5,460 (US\$66.70) to ¥3,600 per month to try and re-ignite their subscriber growth and stop the outflow of subscribers to cheaper LTE mobile broadband services.⁸⁹

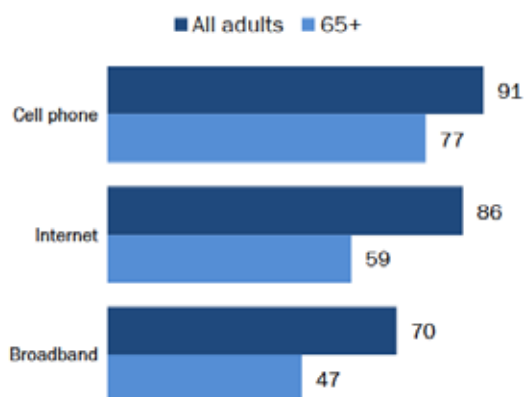
While wired subscriber growth has slowed in Japan and Italy, it remains positive despite declining populations in both nations.⁹⁰

D. Subscription Rate by Age Group

In the United States, subscription rates vary by age group, with seniors much more reluctant to use the Internet - and other forms of technology - than younger people.

Seniors continue to lag in tech adoption

Seniors vs. all American adults 18+



Pew Research Center's Internet Project July 18-September 30, 2013 tracking survey.

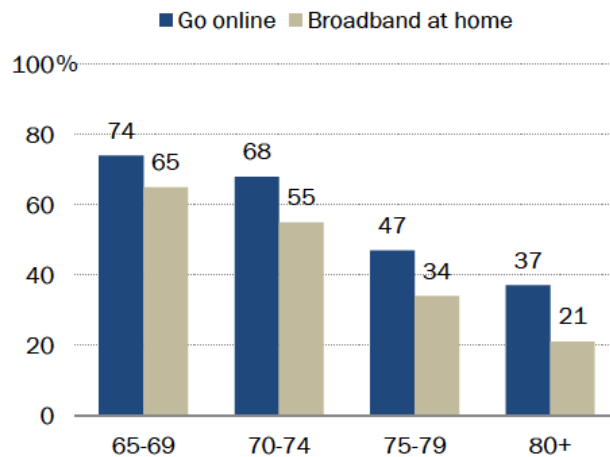
PEW RESEARCH CENTER

Figure 44: Seniors are technology averse. Source: Pew.⁹¹

Within the senior category itself, older seniors are more technology-averse than younger ones.

Among seniors, internet and broadband use drop off around age 75

% within each age group who ...



Pew Research Center's Internet Project July 18-September 30, 2013 tracking survey.

PEW RESEARCH CENTER

Figure 45: Older seniors are more technology-averse than younger ones. Source: Pew.⁹²

Similarly, seniors have low rates of computer ownership, and a larger gap between computer ownership and Internet use than younger people.

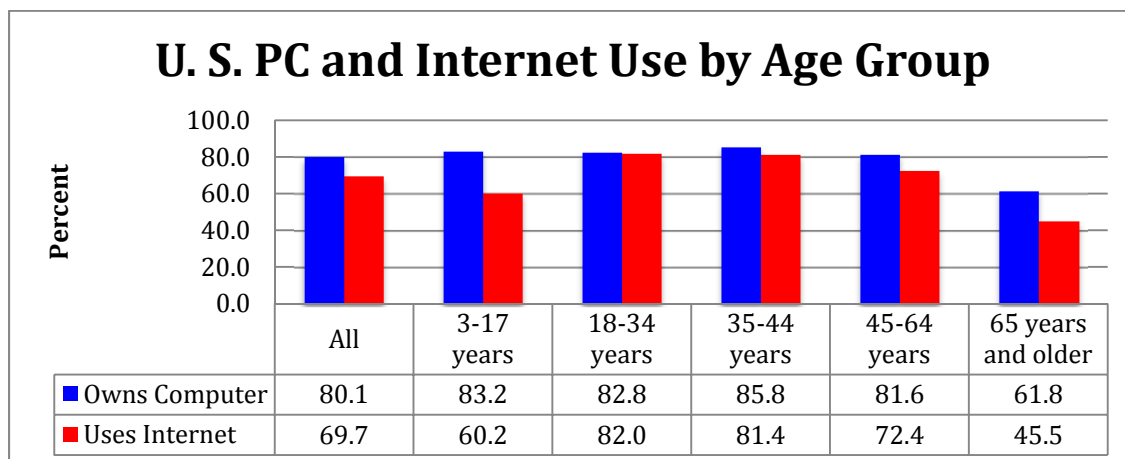


Figure 46: U. S. Internet Use in thousands by Age and Computer Ownership: 21011. Source: Census⁹³

The low rate of Internet use by seniors who own computers shows that the reluctance to go online is not simply a matter of low rates of computer ownership as some have maintained. It also suggests that outreach programs aimed at the senior population are

likely to increase seniors' rate of Internet use even when not combined with programs to subsidize computer ownership. With the rise of the tablet and the smartphone, computers are no longer Internet prerequisites; the primary factor is interest.

E. Policy Issues

The social benefits of broadband depend on broad adoption. Until nearly all Americans use broadband services, paper forms and telephone interactions can't be fully replaced by less expensive and more valuable broadband modalities. Consequently, broadband users have a vested interest in broadband use by others. Broadband service providers and Internet businesses also have interests in broader adoption, as the non-adopter population represents additional revenue opportunities at relatively low cost.

For this reason, a number of firms from broadband service providers such as Comcast to web services firms such as Facebook have developed initiatives to encourage broader adoption of the Internet both in the U. S. and in the rest of the world. Other governments have also been active in promoting Internet use through outreach programs; these have been particularly successful in Korea and Singapore, for example.⁹⁴

Public/private partnerships are a useful policy avenue to pursue for stimulating Internet use, as government and the private sector share the benefits of broader adoption. Broadband deployment - at basic performance levels - is a solved problem in the U. S. at this point, so it's reasonable to redirect at least some Universal Service funds toward demand creation programs, but the private and non-profit sectors are best equipped to manage adoption programs. Researcher John Horrigan finds that Internet use is most highly valued by members of social groups in which Internet use is common.⁹⁵

4. Broadband Performance

Network performance measurement is difficult because a number of non-network factors always intrude in any system of network measurement. The Internet is an "end-to-end" system in which key component - the TCP module - runs on the end user's computer, outside the control of the network operator. The performance of end-user computers affects the test scores obtained by TCP-level tests such as Ookla Speedtest and Akamai.

The other end of a performance test is either a test server located at some location on the Internet or a commercial server in an unknown condition of load and capacity. While the path to a test server can be controlled, it doesn't reflect the performance that users experience. But the capacity of web servers, another issue outside the control of the network operator, dominates experienced performance. FCC measurement of web page load time shows that the web server and browser account for 75 percent of load time when users are on a 50 Mbps connection. Other web page load tests, such as Akamai's, report load times five times higher than the FCC measurements.

The Internet is a mesh of millions of paths between clients and servers, each of which exhibits different capacity, delay, and loss characteristics. The diversity of these paths is not easily captured, hence broadband testing tends to be done by specialized test devices such as the SamKnows "White Box" that connect directly to the user's

cable modem or DSL access device. The data recorded by such devices is influenced by their distribution, however. As in any other kind of polling, it's critical to survey a representative sample of the population, but the FCC admits that SamKnows White Box users often alter their services and therefore are not as representative as they should be.

Sampling is an even more serious problem with crowd-sourced systems such as OpenSignal and Ookla Speedtest. These systems are entirely self-selected, so they're no more representative than web site polls of political questions. In the Net Index sample data, there's no correlation between the number of tests run in each nation and the Internet user population; 70 tests from Canada vs. seven for Germany, for example. TCP performance is influenced heavily by distance between client and server - this is the reason for Content Delivery Networks - but the sample data shows distances as short as eight tenths of a mile and as long as 8,000 miles. The Net Index tests are regarded as reasonably reliable for each instance of testing, allowing for end system performance variations, but their lack of a representative sample population undermines their validity. OpenSignal, a system that purports to measure mobile network performance, suffers from the same limitations.

Consequently, no single network performance test is definitive and it's necessary to synthesize results to develop a useful picture, in much the same way that Nate Silver synthesizes political polls.

A. Application Requirements

Before we delve into the arcana of broadband performance measurement, it's worthwhile to frame the subject in the proper context. Broadband performance is often an issue of national pride or a stalking horse for a desired regulatory outcome, such as nationalization. It's easy to recognize outcome-driven rhetoric in discussions of network performance: when speakers make vague or anecdotal claims about "other countries" who are alleged to be doing wonderful things that ones own country should mimic, something may well be amiss. No prizes are given to the fastest or even cheapest networks; the bounty of network performance comes in the form of adequate access to applications.

If a nation's networks are fast enough, cheap enough, reliable enough, and pervasive enough to enable citizens to enjoy the full panoply of applications, citizens win. If networks are even faster than they need to be, there's no additional prize, but there may be one for less expensive networks than ones that push the boundaries of affordability. A number of studies have attempted to quantify application requirements, but they tend to be flawed in similar ways as the studies that attempt to quantify broadband's contribution to GDP; both types of studies tend to be outcome-driven.

For example, Saunders, McClure, and Mandel emphasize download times for entertainment media files.

Table 3: Entertainment media file sizes and download times at different connection speeds [9].					
Media type and file size		Network download speed			
Type	Size	4 Mbps	10 Mbps	20 Mbps	50 Mbps
four-minute song	4 MBs	7.6 seconds	3 seconds	1.5 seconds	0.6 seconds
five-minute video	30 MBs	57 seconds	22.9 seconds	11.4 seconds	4.5 seconds
nine-hour audio book	110 MBs	3.4 minutes	1.4 minutes	42 seconds	17 seconds
35-minute TV show	200 MBs	6.4 minutes	2.5 minutes	1.27 minutes	30 seconds
45-minute HD TV show	600 MBs	19 minutes	7.6 minutes	3.8 minutes	1.5 minutes
two-hour movie	1.5 GBs	47.6 minutes	19 minutes	9.5 minutes	3.8 minutes
two-hour HD movie	4.5 GBs	2.3 hours	57 minutes	28.6 minutes	11.4 minutes

Figure 47: Download times for Entertainment Media Files. Source: Saunders et al.⁹⁶

They seek to connect file download times to streaming media services:

*Downloading media. Downloading movies and TV shows is big business for companies like Netflix, Hulu, and Apple. However, all of these companies perform a balancing act between the quality of the video content provided and the amount of bandwidth consumed by the user (Moon, 2012). These companies are concerned with bandwidth consumption due to some Internet service providers (ISPs) placing data caps on customers that consume more than a certain data amount each month.*⁹⁷

But streaming media services don't download entire files before they begin to play them out; they simply fill a small buffer and then continue to download as they play. The 9.5 minutes it may take to download a two-hour movie at 20 Mbps is utterly unimportant; with Netflix, the movie begins to play in less than five seconds. There is a certainly a case to be made for networks that permit rapid movie playout⁹⁸; but movie playout needs are satisfied by an honest 10 Mbps connection every bit as well as they would be by a 100 Mbps connection permitting two minute file downloads.

Similarly, common interpersonal communications such as Instant Messaging, Twitter, and email are perfectly usable on dial-up connections and don't even provide an argument for broadband. Web surfing is different, however, as it clearly does require broadband connections to be usable. Traditional human factors research suggests that web pages need to load in five seconds or less to be considered usable.⁹⁹

More recent thinking suggests that users prefer commerce and entertainment sites that load fast, and an entire Content Delivery Network industry has developed around web acceleration to enable them to do so. But CDNs reduce the load times of web pages not by making more network bandwidth available to the user, they do their magic by reducing distance, circumventing TCP design defects, and increasing server performance with faster CPUs and storage.¹⁰⁰ Web page load times are dominated by server performance rather than network constraints at broadband connection speeds greater than a few megabits per second in any case, as we will see when we discuss web page load times below.

Some applications have hard performance limits, however: Immersive Video Conferencing requires an actual 15 Mbps at 1080p, plus additional headroom to

recover from delays common on the public Internet at sub-second intervals.¹⁰¹ The routine use of high-definition medical images might well require 300 Mbps to transfer images in less than five seconds if they have the characteristics described in the Saunders paper, but this would be a commercial network connection, not a residential one.¹⁰² Looking into the future, the only applications that would require capacities greater than 100 Mbps and less than one Gbps are holographic conferencing and multi-party video conference hosting; simple participation in a multiparty video call is no more demanding than Cisco Telepresence.

The FCC's current proposed benchmark for adequate broadband capacity is 10 Mbps for all locations, urban and rural; if we double that value we can safely assume that no meaningful current application is left behind.¹⁰³ Consequently, it's reasonable to assume that 20 Mbps is the threshold for desktop applications and 10 Mbps of mobile bandwidth is the threshold for smartphone applications.

B. Wired Network Performance

Wired network performance is easier to measure than wireless, but all forms of network capacity measurement are difficult, as noted. Wired network tests tend to be more reproducible and less device-dependent than mobile tests, but each suite measures a different thing. Explanations of the eccentricities of each method will be found in the following text.

i. Akamai Typical Broadband Speeds and Adoption

To examine current deployment and adoption trends and to examine deployment and adoption by capacity, one of the most valuable data sets is Akamai's quarterly "State of the Internet" report that has measured broadband performance and adoption since mid-2007. The Akamai data focus on the observed performance of actual networks, so they see a different part of the broadband ecosystem than the one surveyed by artificial speed tests such as SamKnows and Ookla. Akamai's data allow us to see trends in the deployment and use of networks typical of both the Basic and the Advanced Broadband Stages.

Since the 3rd Quarter of 2007, Akamai has collected data on the percentage of TCP connections transferring data at 4 Mbps or higher; this measurement is termed "broadband adoption". Akamai's data are often reported in the press as measurements of network performance, but this is only true when they're used carefully. Akamai measures TCP connections rather than gross network capacity, and it does so under real-world conditions. In most Internet uses, multiple TCP connections run in parallel, so a measure of one does not stand in for network capacity.

Akamai's "Average Peak Connection Speed" (APCS) is a fair proxy of network capacity, but its more commonly cited "Average Connection Speed" (ACS) is not. ACS is taken in shared capacity settings, one in which multiple TCP connections run in parallel, taking bandwidth away from each other in at least three different ways:

1. Such applications as web browsing use 4 - 8 TCP connections at the same time, so each TCP connection only represents a fraction of the network's capacity. The average web page requires 37 TCP connections.¹⁰⁴
2. When multiple users share a common broadband connection - the typical case in homes, schools, and businesses - each user can only consume a fraction of the overall capacity of the connection when other users are active.

- Some applications – such as Netflix video streaming – self-limit TCP stream capacity in order to conserve server resources.

Akamai doesn't aggregate all TCP connections in use on a given IP address at the same time because it can't see all of them. Netflix, for example, does not use Akamai's CDN any more. Akamai's ACS simply averages the capacities of the TCP connections it sees.

Consequently, achieving an average TCP connection speed of 4 Mbps or more requires a peak network capacity of 15 Mbps or more. 4 Mbps is the threshold to the most common data applications the Internet has to offer in the most common sharing scenarios. Netflix consumes an average of 3.5 Mbps on the fastest networks.¹⁰⁵

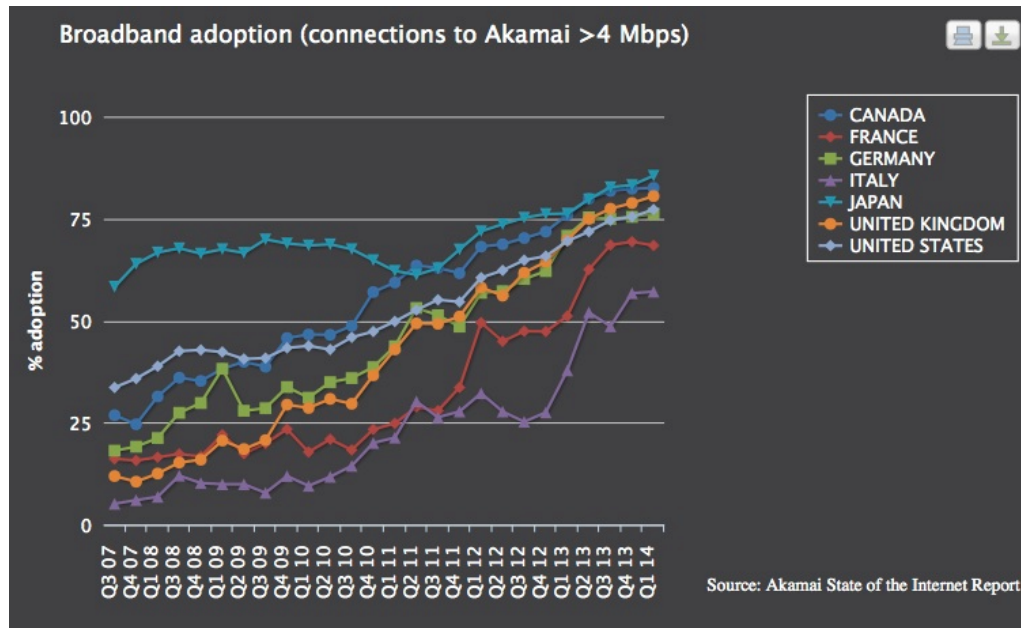


Figure 48: Medium-Capacity Broadband Prevalence, 2007-14. Source: Akamai.¹⁰⁶

This graph shows the prevalence of connections with average measured capacities greater than 4 Mbps in the overall mix of connections measured by Akamai as basic broadband.

This graph is remarkable in two respects: it's the only graph of G7 broadband that shows the U. S. ranking lower than second and it's the only graph that fails to show Japan substantially ahead of the second place nation; in fact, Canada and Japan are in a virtual dead heat, separated by less than one percentage point. In light of the Japan's heavy spending for high capacity broadband, this may be the most expensive percentage point in the entire data set.

Reports from the most recent quarter (1Q 2014) and the year-earlier quarter show substantial progress in Italy, France, U. K., and Japan.

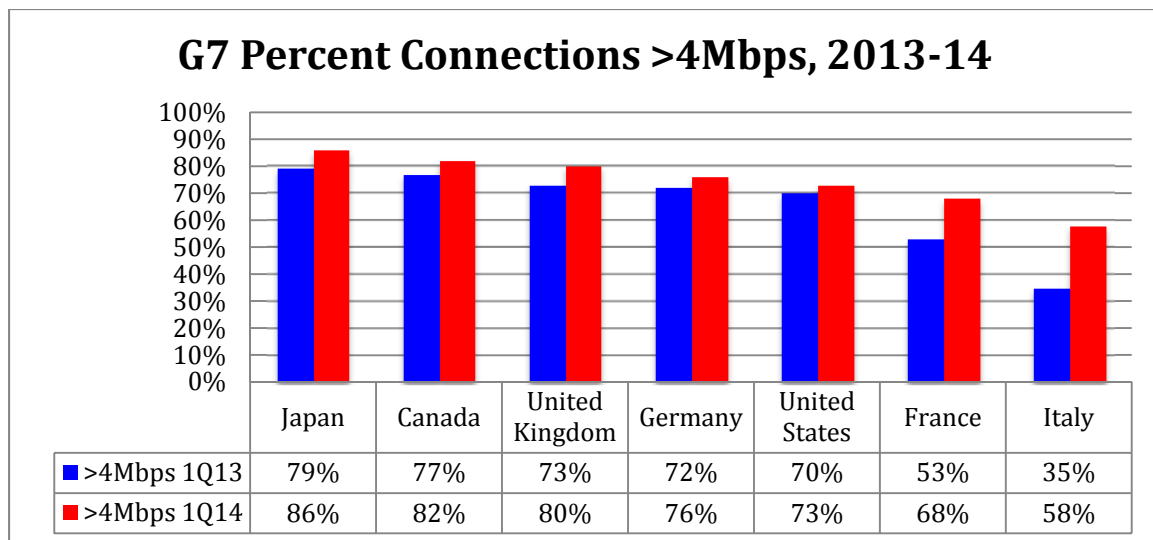


Figure 49: G7 Percent Connections >4Mbps 1Q 2013-14. Source: Akamai¹⁰⁷

ii. Akamai High Broadband Speeds and Adoption

Since 3rd Quarter of 2007, Akamai has collected data on the percentage of TCP connections transferring data at 10 Mbps or higher; this measurement is termed “high-speed broadband adoption”. TCP doesn’t always transfer data at the full capacity of the underlying broadband network, for at least four reasons:

1. Such applications as web browsing use multiple TCP connections at the same time, so each TCP connection only represents a fraction of the network’s capacity.
2. When multiple users share a common broadband connection – the typical case in homes, schools, and businesses – each user can only consume a fraction of the overall capacity of the connection when other users are active.
3. Some applications – such as Netflix video streaming – self-limit TCP streams capacity in order to conserve server resources.
4. Short-lived TCP connections don’t graduate from the initial state, performance-impaired “Slow Start”, to full capacity before they’re abandoned.

Consequently, achieving an average TCP connection speed of 10 Mbps or more requires a peak network capacity of 40 Mbps or more. 10 Mbps of TCP Average Connection Speed is therefore the threshold to the most demanding data applications the Internet has to offer in the most intensely shared scenarios.

High-speed broadband adoption data follows a familiar pattern: Japan has the highest score; the U. S., U. K., and Canada are next; and continental Europe lags behind. This pattern appears throughout G7 performance data.

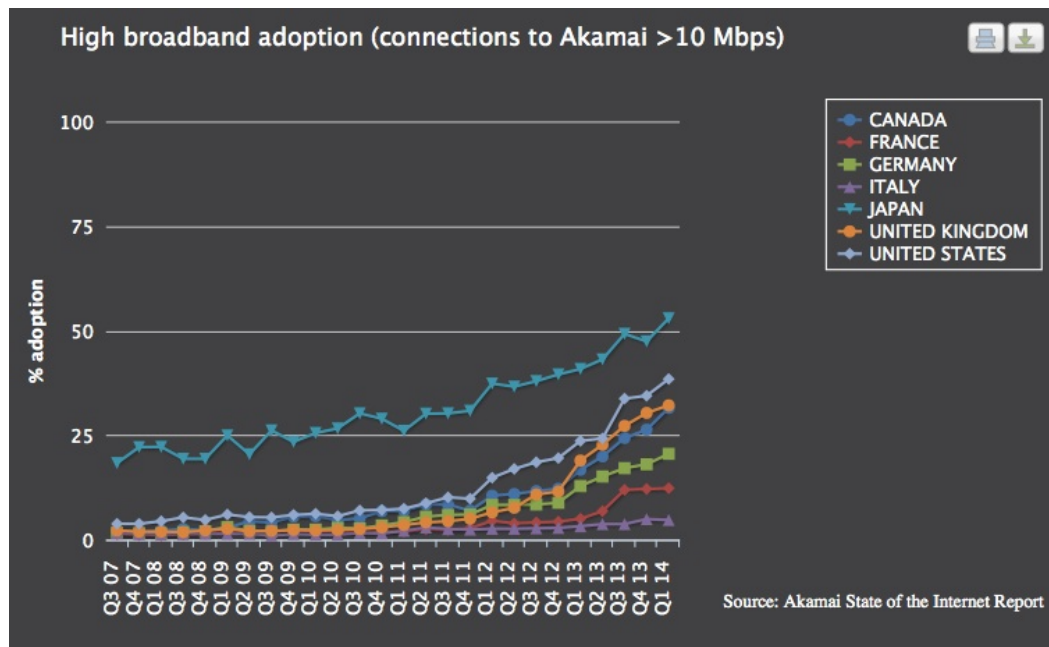


Figure 50: High Capacity Broadband Prevalence, 2007-14. Source: Akamai.¹⁰⁸

In the most recent quarter, no nation showed more than 50 percent of its TCP connections running consistently faster than 10 Mbps, but all showed annual improvement. France made the most progress, 146 percent, but it remains second to last at 12.3 percent.

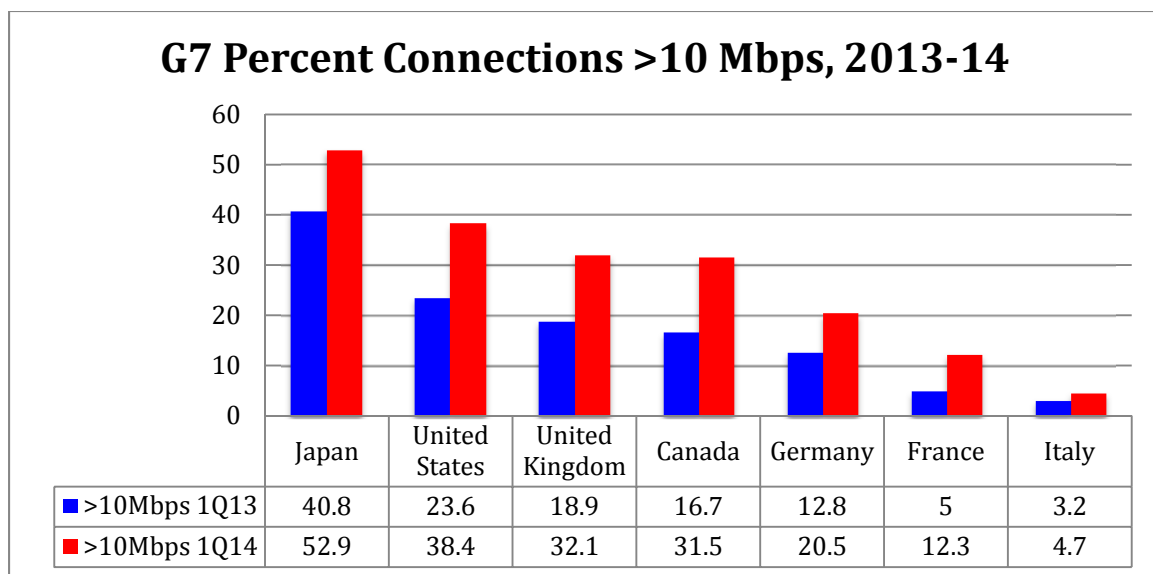


Figure 51: Percent Connections >10Mbps Q1 2013-14. Source: Akamai¹⁰⁹

All nations made improvements in the Q1 2014⁵ over the previous quarter, which is unusual. In the preceding quarter, Japan showed a quarterly decline. Occasional declining scores are consistent with broadband dynamics: as user populations grow, usage becomes more intense, or applications are revised to consume more resources, performance will often degrade until providers add capacity to their networks at

bottleneck locations. Upgrades are not always made on time and are not always made to the right locations, so a certain amount of slippage is inevitable.

In other words, the saw tooth pattern often seen in quarter-to-quarter historical network performance data is caused by usage catching up to capacity and capacity then increasing. Capacity bottlenecks don't generally appear in the last mile of cable and fiber networks; more commonly, they're found in aggregation points. Consequently, Japan's seven upgrades and the U. S.'s five since 2007 have only rarely resulted in higher advertised speeds. Nations rarely decline in speed over an entire year, however.

iii. Akamai Average Network Capacity Measurement

As previously noted, Akamai measures two capacity averages, "Average Peak Connection Speed" and "Average Connection Speed, both of which are commonly reported in a misleading manner.¹¹⁰ The "Average Peak Connection Speed" is the mean of the highest TCP connection speeds seen on all the IP addresses in the nation or region, while "Average Connection Speed" is the mean all TCP connections.

These averages differ by a ratio of 4:1, which indicates that the typical measurement scenario involves some mix of IP address sharing, four or more active TCP connections per user (a characteristic of web browsing), a rate-limited service such as video streaming running at one fourth the network's capacity, TCP connections in the "slow start" impairment condition, or upstream network congestion¹¹¹.

Some commenters have asserted that the discrepancy between average TCP connection speeds and average peak TCP connection speeds always comes down to network congestion¹¹², but this claim is not consistent with measurements of advertised vs. actual speeds in the U. S.¹¹³ and in Europe¹¹⁴.

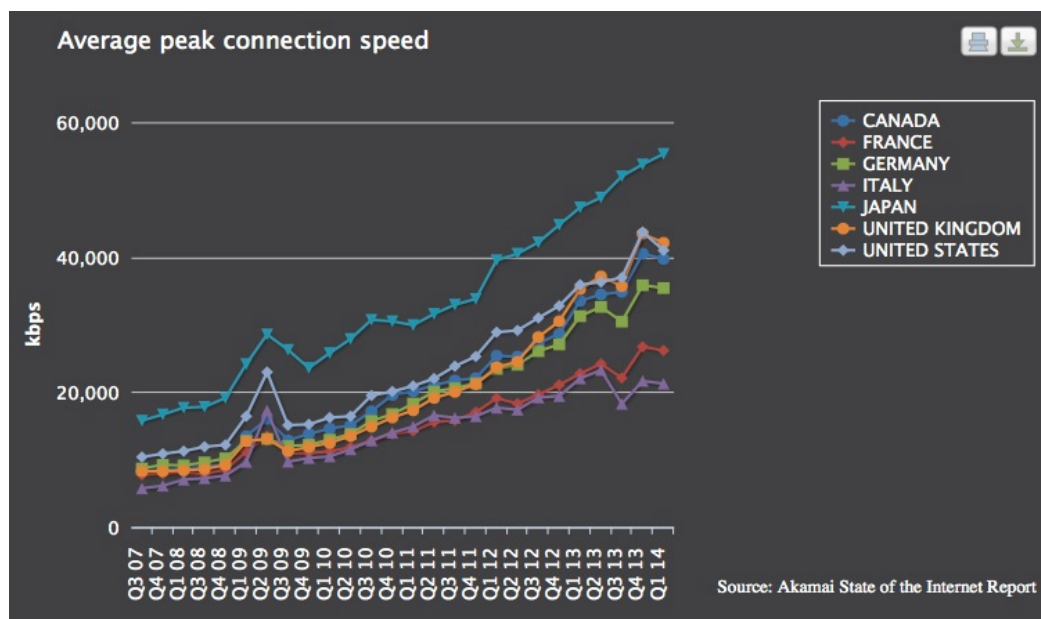


Figure 52: Network Capacity in G7 Nations, 2007-14. Source: Akamai¹¹⁵

If we want to know how much capacity a nation's broadband networks provide, on average, we must use Akamai's "Average Peak Connection Speed" measurement.

For the most recent two quarters reported, Q4 2013 and Q1 2014, it places the United States at 43.7 and 40.6 Mbps respectively, behind Japan and slightly behind the U. K.'s 43.5 and 42.2 Mbps.¹¹⁶ Continental Europe brings up the rear with capacities as low as 21.4 Mbps in Italy.

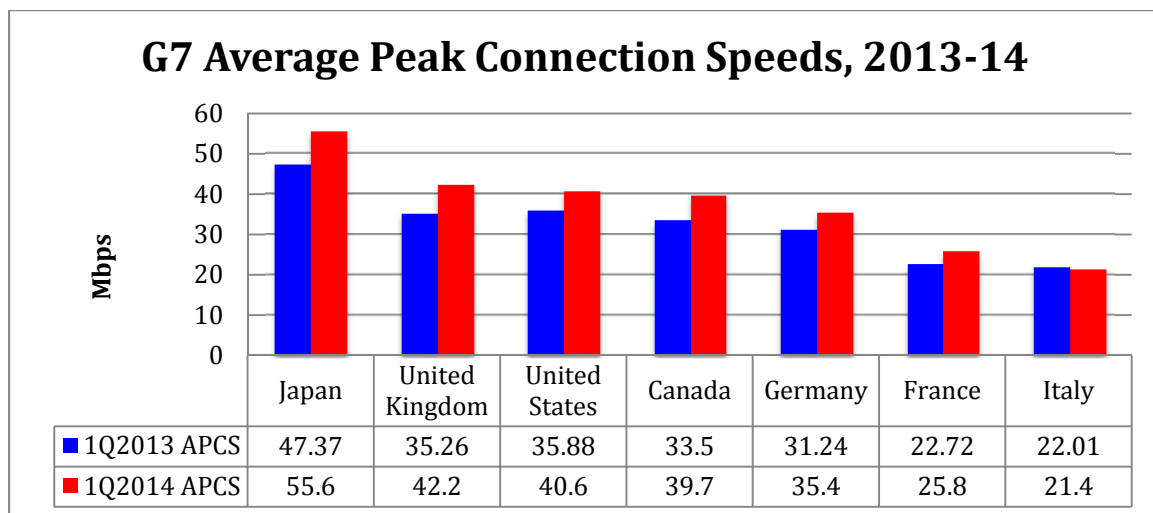


Figure 53: G7 Broadband Capacities in Q1 2014. Source: Akamai.¹¹⁷

Average Peak Connection speed is helpful in calculating average web page load time and the download time of large files; it is not particularly helpful in connection with video streaming because all media streaming applications are self-limited because of server capacity concerns. On America's gigabit networks, such as Google Fiber, Netflix streams at less than 4 Mbps, for example.¹¹⁸

iv. Ookla Wired Network Speed Tests

Unlike Akamai, which measures a representative sample of Internet users while they're engaged in their normal activities, Ookla (also known as "Speedtest.net" and "Net Index") is a crowd-sourced test that only measures the performance of networks and systems selected by particular users. Speed tests are typically run to troubleshoot problems and to verify upgrades; many users test the same path several times in quick succession, others test only once, but most users don't run the test at all.

There are considerable discrepancies between Akamai's Average Peak Connection Speed - the metric that best approximates network capacity - and the Ookla results. Akamai ranks Japan at the top of the G7 in download speed, which is the expected result given the prevalence of 100 Mbps and 1000 Mbps connections in Japan. It ranks France sixth, which is also consistent with the nature of that nation's infrastructure; France is predominately a first generation DSL nation, with very low penetration of VDSL, DOCSIS, and FTTH. But Ookla inexplicably ranks France at the top of the G7 and Japan in fifth place. Akamai ranks the U. K., the U. S. and Canada in a virtual tie for second place, but Ookla ranks Canada in sixth place. Both tests agree on ranking the U. K. second, the U. S. third, and Italy last, however.

Ookla reports measurements on a monthly basis, and there is considerable bounce from month to month in their data; Akamai releases measurements once a quarter, and there is generally very little bounce in their data (some quarters have been anomalous, such as 2Q 2009, but uniformly so across the entire set of nations.)

The best way to use Ookla data is to isolate changes on a given connection, its intended purpose; its validity across nations is dubious because of sampling issues. It's noteworthy that the most aggressive critics of broadband in America rely on Ookla data to support their "falling dangerously behind" claims.¹¹⁹ These critics are victims of bad data for the most part.

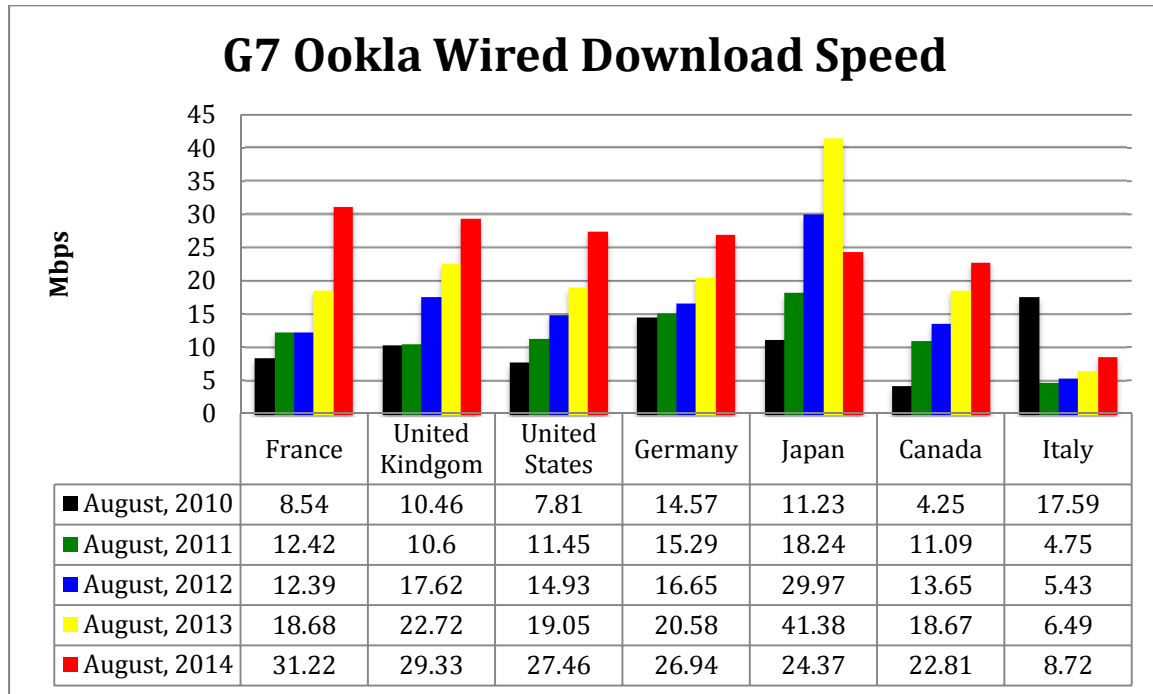


Figure 54: Ookla Survey of G7 Wired Network Speed. Source: Ookla.

v. Resolving Wired Measurement Discrepancies

Because of the discrepancy between Ookla and the known characteristics of broadband infrastructure, it's best to discard Ookla's reports of national broadband speed altogether. Not only is Akamai consistent with expected speeds, it's consistent with speeds measured by SamKnows. Hence, Akamai and SamKnows together give us a consistent picture represented by two independent measurements. As much as possible, we should examine at least two sources of data before drawing any conclusions, as the scientific method requires.

C. Mobile Network Performance

Mobile network performance is even harder to measure than wired network performance. Mobile networks depend on the same highly variable wired infrastructure that exhibits extremes of congestion and server overload, and they also feature an additional set of variable related to radio interference, signal strength variations with distance from the cell tower, and environmental barriers to a clear signal.

As if these factors aren't complicated enough, handheld devices also have slower processors than desktop and laptop computers, and many forms of testing reflect as much on processor power as on network capacity. Dedicated test devices like the SamKnows White Box are not currently used for mobile network testing, so the accuracy and reproducibility of mobile network tests is questionable. All mobile

network test data sets show a much larger range of variations in test data points than wired tests do. This is reflected in the “peak to average ratio” in tests such as the Akamai/Ericsson test suite.

i. Akamai/Ericsson Measurements of Actual Mobile Broadband Speeds

In the past, Akamai/Ericsson reported mobile speeds on a network-by-network basis, but beginning with the 1Q 2014 report, measurements are aggregated at the country level and combined with a high-speed adoption figure reflecting the percentage of connections measured at 4 Mbps or higher. This speed is indicative of 3.9G/4G radios at an underlying link rate at least double 4 Mbps because of the way the streams are measured (see explanation of Akamai test methodology in the wired section above.)

First movers are penalized in mobile tests. The U. S. now shows pedestrian mobile speeds, ranking next to last in the G7 for a number of reasons. It was the first nation to adopt LTE. This means we have more LTE users in proportion to the overall mobile user population, older and slower handsets, and greater contention for spectrum. Spectrum is more constrained in the U. S., where it is allocated inefficiently in small blocks; and LTE is a premium service in other countries but a generic one in the U. S. The Akamai test does not reflect Wi-Fi usage, which further penalizes the U. S.

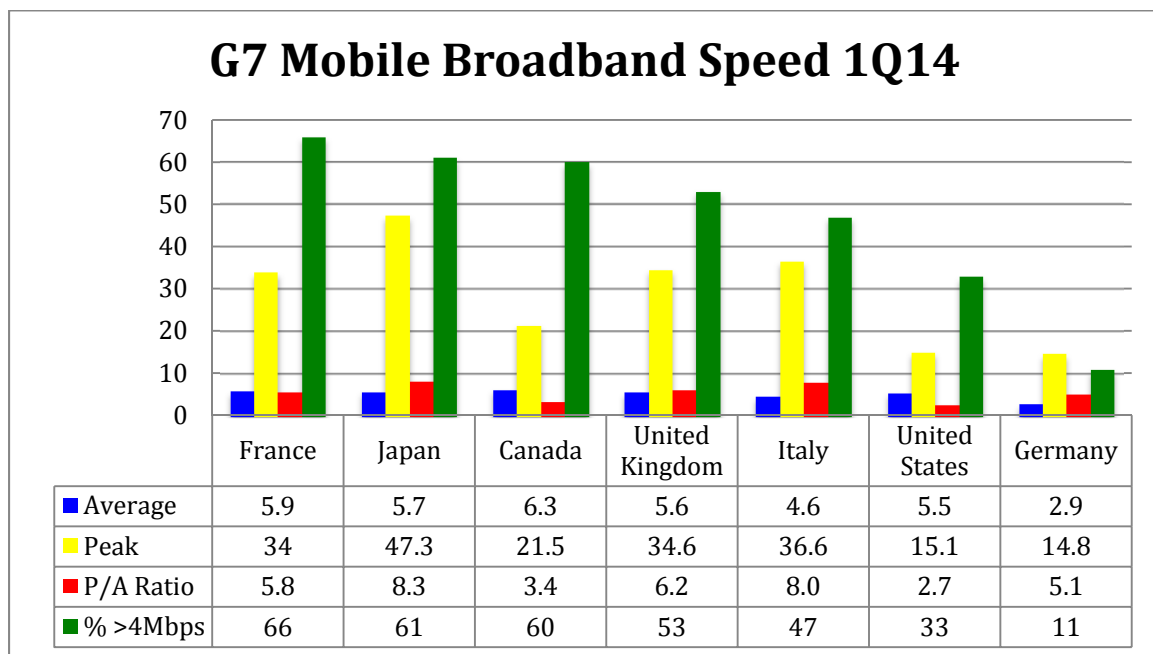


Figure 55: G7 Mobile Broadband Speed 1Q 2014. Source: Akamai

It's interesting that one nation with very poor wired capacity, France, scores very well on mobile capacity, while other nations poorly connected by wire are also poorly connected by mobile, Italy and Germany. This discontinuity may be a clue that policy differences are afoot in Continental Europe, but it could also be a testing artifact. Such discontinuities are one reason that it's useful to examine test data carefully.

The poor showing of the U. S. in mobile download speed is also an indication that our networks are in need of an upgrade to the next generation of mobile, LTE Advanced. This upgrade is indeed in progress: the fastest mobile network in the U. S. today is the recently upgraded T-Mobile system. Verizon is already rolling out an LTE Advanced

system under the name “XLTE”.¹²⁰ Sprint is rolling out, “Spark”, an LTE Advanced system promising speeds up to 180 Mbps by 2015.¹²¹ AT&T is operating LTE Advanced in Chicago and other markets already, with a national rollout to follow shortly.¹²² Consequently, the test scores should show some major differences a year from now.

ii. Cisco Measurement of Average Mobile Broadband Speed

Cisco uses a crowd-sourced test tool, similar to OpenSignal and Ookla, to measure mobile data speeds. Their most recent data, from August 2013, shows the expected rank order for that period, allowing for the mix of 3G and 4G networks in G7 nations, but speeds are very low, less than 1 Mbps in all cases. This test is probably accurate in a relative sense, but may not be reliable in an absolute sense.

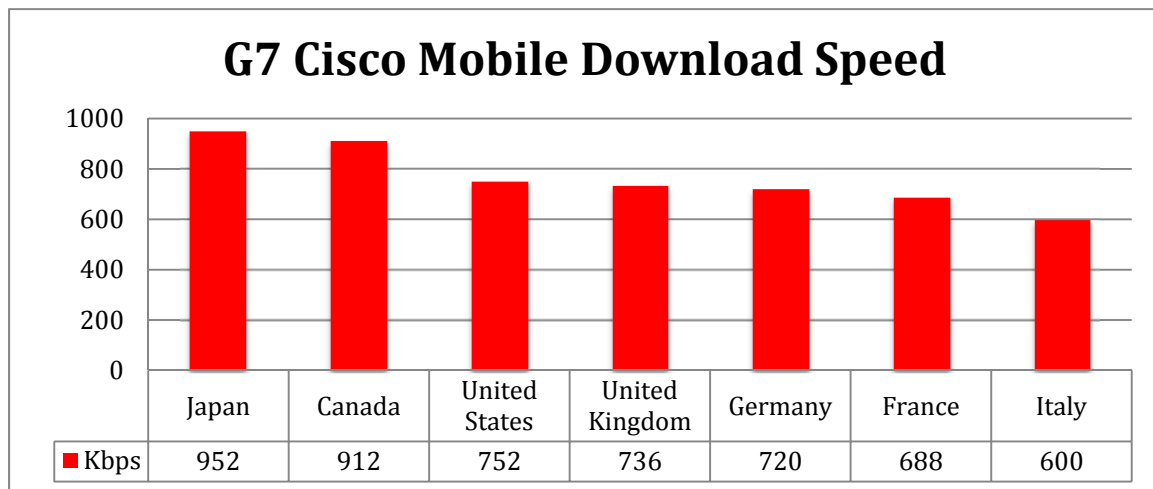


Figure 56: Average G7 Mobile Download Speed, August 2013. Source: Cisco.¹²³

The Cisco test results indicate that the LTE rollout had not begun in France as of last summer.

iii. Ookla Mobile Network Speed Survey

Ookla also conducts mobile network testing using the same crowd-source methodology it uses for its wired tests, and with the same limitations. Like Akamai, it shows high speeds in France in the most recent test period, and low speeds in Italy. Speed in France have undergone a major leap forward from its state a year ago when the Cisco test was conducted: France has risen from 6.7 Mbps to 16.23 Mbps, an impressive feat that can only indicate a major network upgrade. All G7 nations advanced to some extent, although Canada’s improvement was extremely slight, less than 500 Kbps. Italy trails its G7 comrades, but doubled its score nonetheless; this probably indicates a major upgrade in the early stages of deployment.

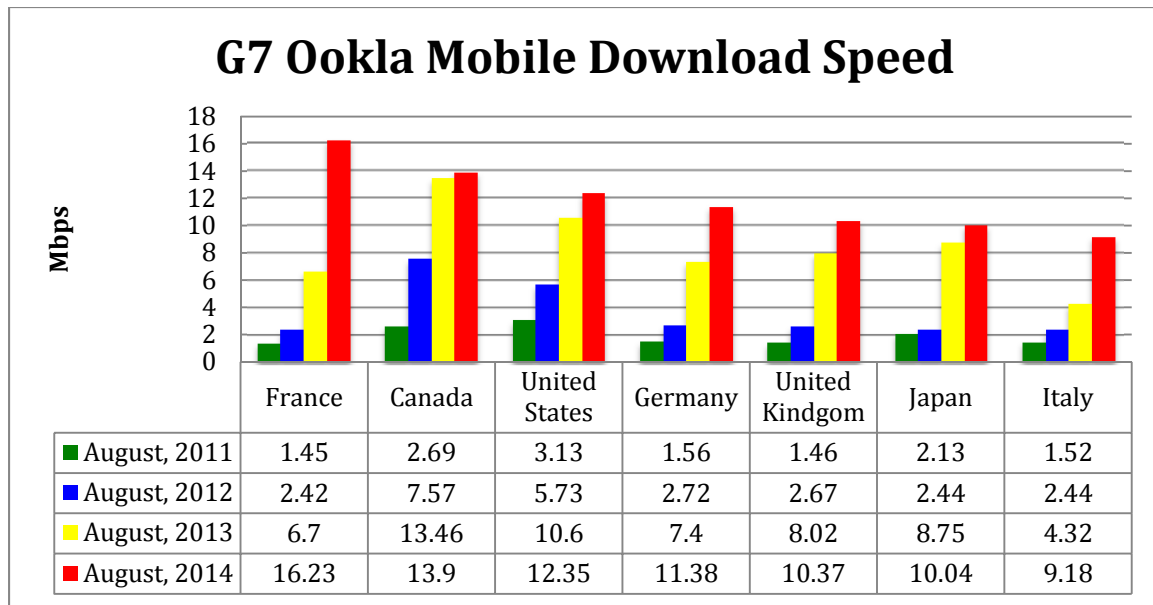


Figure 57: G7 Ookla Mobile Download Speed. Source: Ookla.

Ookla shows the U. S., Germany, and the U. K. clustered close together in the middle of the performance range. All nations show average speeds in the Ookla test of 9 Mbps or more, which is sufficient for users to enjoy the full benefits of the mobile experience. The ratio of fastest to slowest speed in Ookla's look at G7 mobile is less than 2:1, not so large as to impact the user experience significantly.

iv. OpenSignal LTE Speed and Coverage Survey

OpenSignal, a crowd-sourced mobile measurement tool, has published two reports on LTE since February 2013. The most recent report shows coverage as well as speed, which is probably a more accurate and meaningful measure because coverage is less device dependent than speed testing.¹²⁴

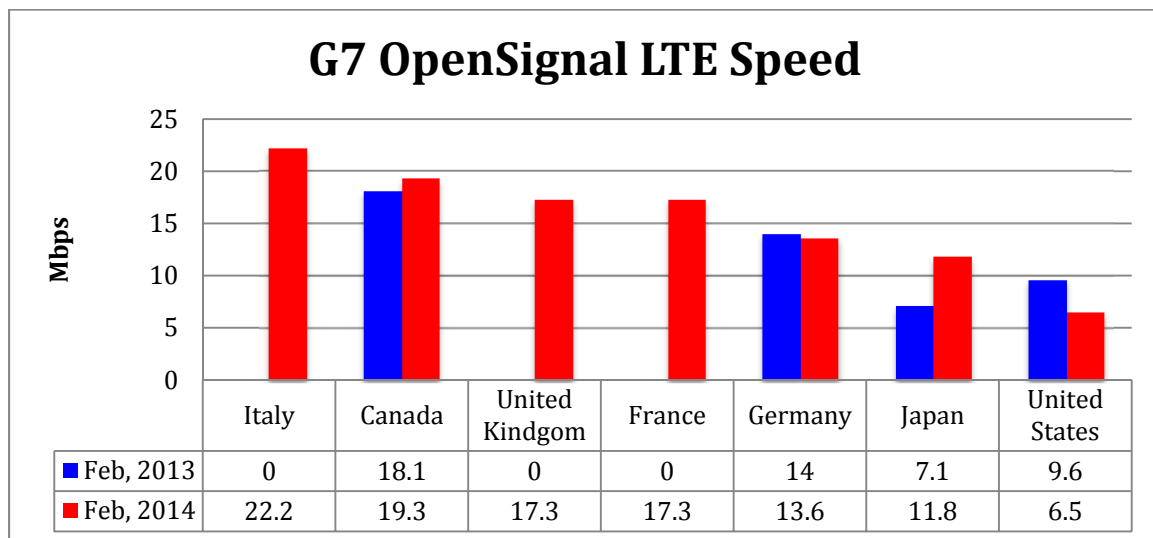


Figure 58: G7 OpenSignal LTE Speed Survey. Source: OpenSignal¹²⁵

OpenSignal's estimates of LTE download speeds diverge from Ookla's and Akamai's by a considerable degree, which shows the impact of test methodology and the self-selection of crowd-sourced measurement at work.

v. Resolving Mobile Measurement Discrepancies

The average download speed of America's mobile broadband networks may be 5.5 Mbps (Akamai), 6.5 Mbps (OpenSignal), 12.35 Mbps (Ookla) or even 775 Kbps (Cisco). We can safely drop the Cisco measurements as an outlier, noting that Cisco has discontinued the project that collected them. The discrepancy between the Akamai and Ookla measurements reflects some methodology; Akamai measures individual real-world data flows, but does not aggregate them. Therefore, a web page that downloads at an overall rate of 40 Mbps will register as four flows of 10 Mbps in the Akamai system when four TCP connections are active at the same time, the normal state of affairs on broadband network. But Ookla runs a test program that aggregates downloads through a single connection instead of simply observing data flows from real web pages.

Akamai measures *Average Peak Connection Speed*, the figure that best approximates network capacity, at 40.6 Mbps on U. S. wired networks, a ratio of about 4:1 over the *Average Connection Speed* of 10.5 Mbps Akamai measures for U. S. wired networks. The ratio of peak to average Akamai measures for U. S. mobile networks is smaller, 2.7:1. This is reasonable, given that mobile browsers are not as heavily parallel as wired ones.

The Akamai Peak measurement for mobile networks in the U. S. is reasonably close to the Ookla measurement at 15.1 vs. 12.35 Mbps. Consequently, the actual average speed of U. S. networks is probably somewhere between the Akamai Peak and the Ookla measurement. But the discrepancies between these two tests are very large in other countries: nearly 5:1 for Japan, 4:1 for Italy, and 3.5:1 for the U. K. Consequently, it appears that the most reasonable way to use mobile speed test scores is on the basis of the median of the three tests.

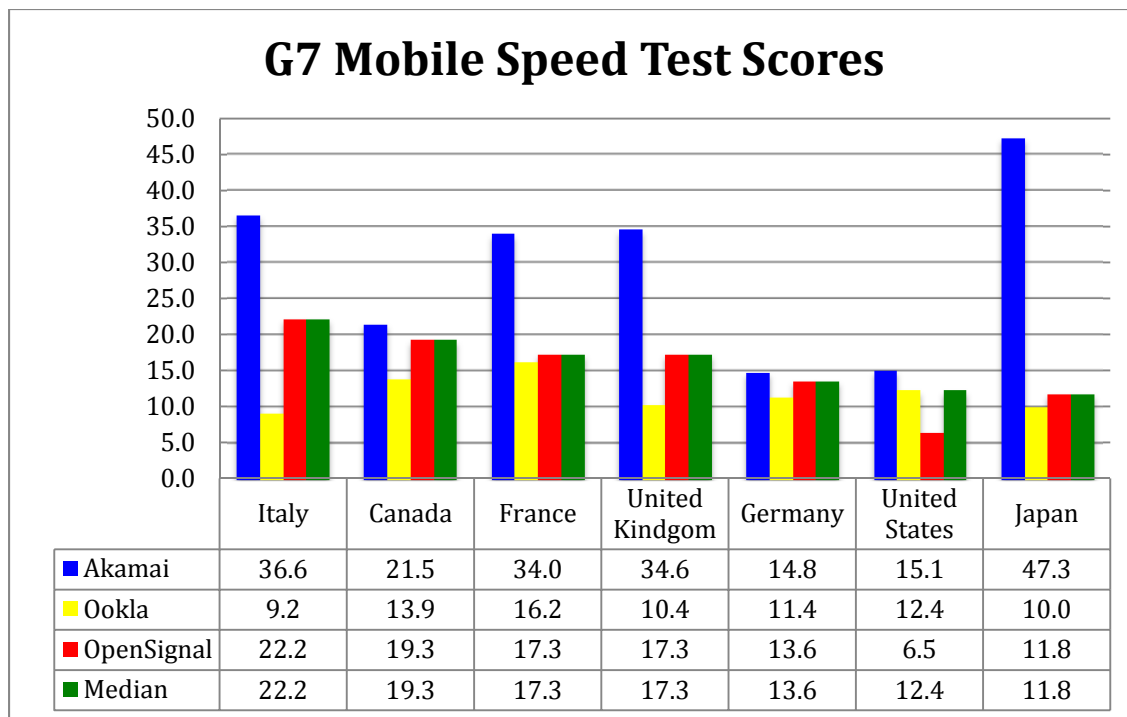


Figure 59: G7 Mobile Speed Test Scores. Source: Akamai, Ookla, OpenSignal.

By the median, Italy and Canada have the highest scores, and the U. S. and Japan have the lowest. This is probably an indication of how heavily the networks are used, as the U. S. and Japan have the most broad adoption of the fastest network technology, 4G/LTE.

D. LTE Speed vs. Coverage

While the OpenSignal data is not reliable as a measurement of speed, it includes data on LTE coverage that's not found in other datasets: OpenSignal measures the percentage of time in which the device was able to access an LTE network in its native mode. This is an indication of the progress of the LTE buildout, as devices will "fall back" to 3G when an LTE signal can't be found. As we should expect, LTE coverage is most pervasive in the U. S. and Japan, the first two nations in the G7 to deploy LTE at scale. The networks with the most pervasive LTE coverage in the G7 are KDDI in Japan and MetroPCS and Verizon in the U. S. The MetroPCS figure is somewhat misleading, as it converted its entire network to LTE and dropped support for older technologies.

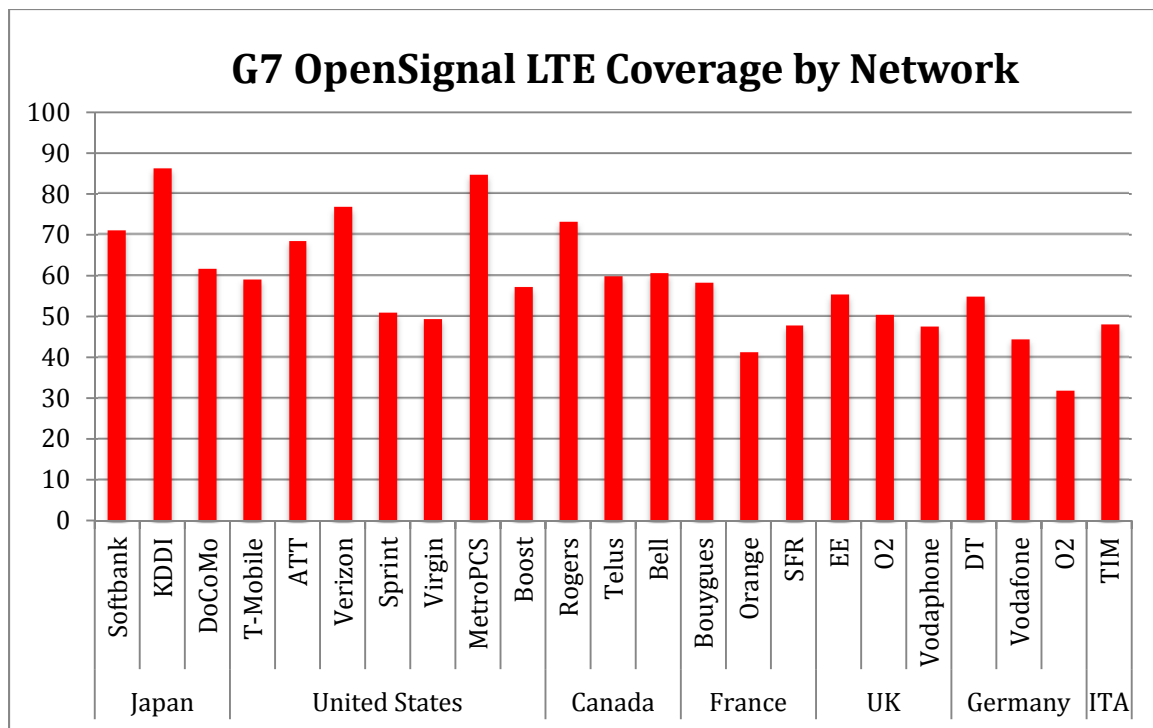


Figure 60: G7 OpenSignal LTE Speed by Network. Source: OpenSignal

Perhaps counter-intuitively, LTE coverage does not correlate positively with speed in OpenSignal's estimation. KDDI ranks second in speed in Japan despite its superior coverage, Verizon ranks third in the U. S., and MetroPCS is next to last in the U. S. with a dismal score of 2.4 Mbps. The MetroPCS score is easy to understand: the firm has very limited spectrum holdings, and has merged with T-Mobile in the interest of spectrum aggregation. But KDDI and Verizon have extensive holdings, and are most likely paying the price of being first movers. The highest speeds are generally found on relatively new deployments, and over time they decline until the next generational upgrade boosts them again.

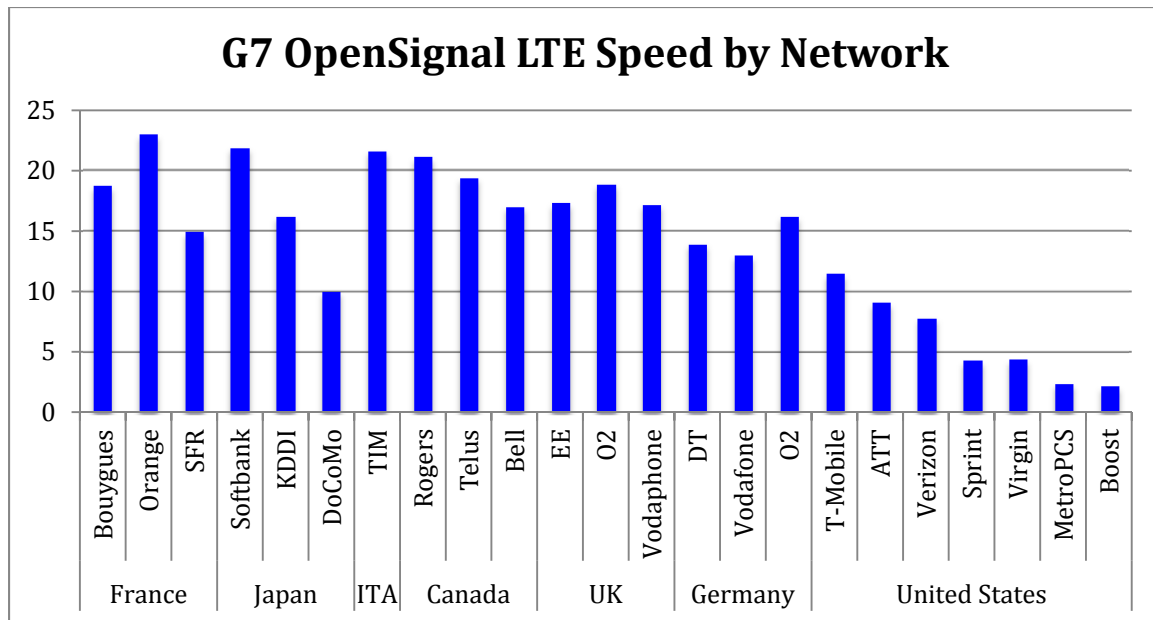


Figure 61: G7 OpenSignal LTE Speed by Network. Source: OpenSignal.

Consequently, the speed of almost any network is an inverse function of time since last upgrade, while the coverage is a positive function of the same factor.

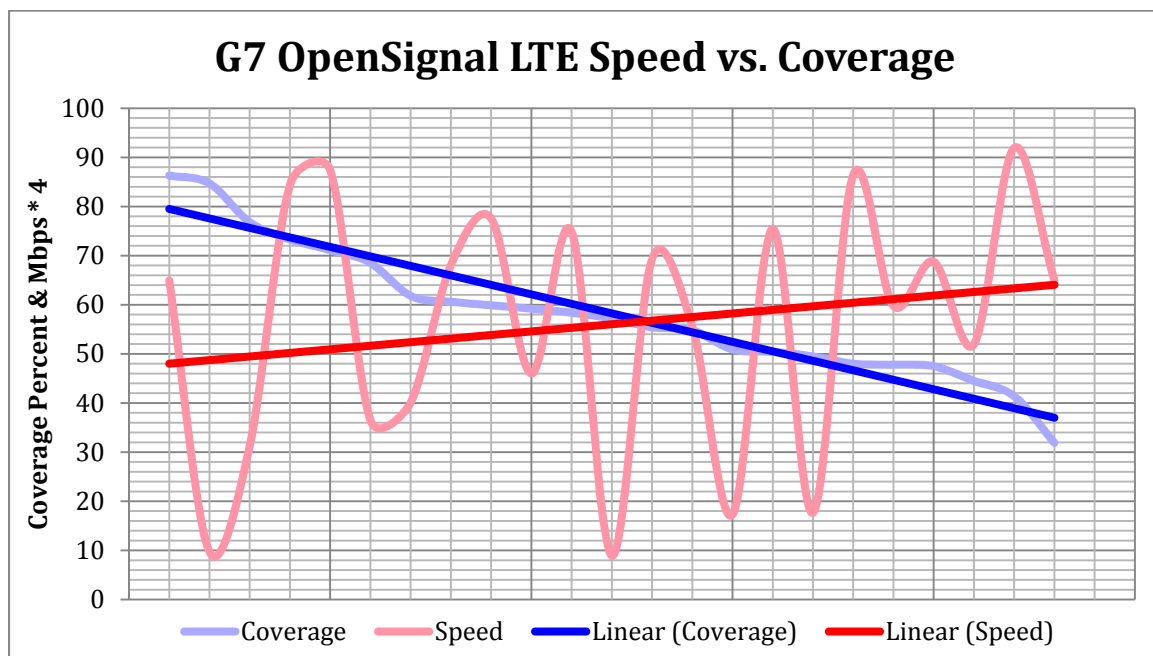


Figure 62: G7 OpenSignal LTE Speed as Function of Coverage Source: OpenSignal

Smoothing the data for speed and coverage across the entire set of LTE networks OpenSignal has mapped in the G7 shows this correlation: where coverage is low, speed is high and vice versa. Consequently, it's prudent to examine both speed and coverage in tandem when passing judgment on the network quality in any nation.

E. Browsing Speed

Speed tests are all well and good, but they don't tell us a great deal about the ways that we experience network services or about the utility that our networks have for day-to-day tasks and applications. In an attempt to bridge the gap between theory and practice, network testing is beginning to collect data on the actual speed of web page loading: both Akamai and SamKnows are making this effort. Web page measurement is at an early stage, but it has already produced interesting results.

i. Predicted Average Browsing Speed

Akamai's "Average Connection Speed" was always intended to measure the browsing experience. This is important to Akamai because their service is primarily used to accelerate the browsing experience. Content Delivery Networks are the Internet's "fast lane", a means of speeding up the user experience for the ten percent of web pages served from CDNs.¹²⁶ But this metric needs some explanation.

Average Connection Speed historical curves closely match the slope of Average Peak Connection Speed curves and differ primarily in scale and variability: ACS values are about a quarter APCS values, and ACS is more variable from quarter to quarter. The variability comes about because many non-network factors are at work in determining the browsing experience, such as the choice of browser, computer speed, choice of applications, and number of users per IP address.

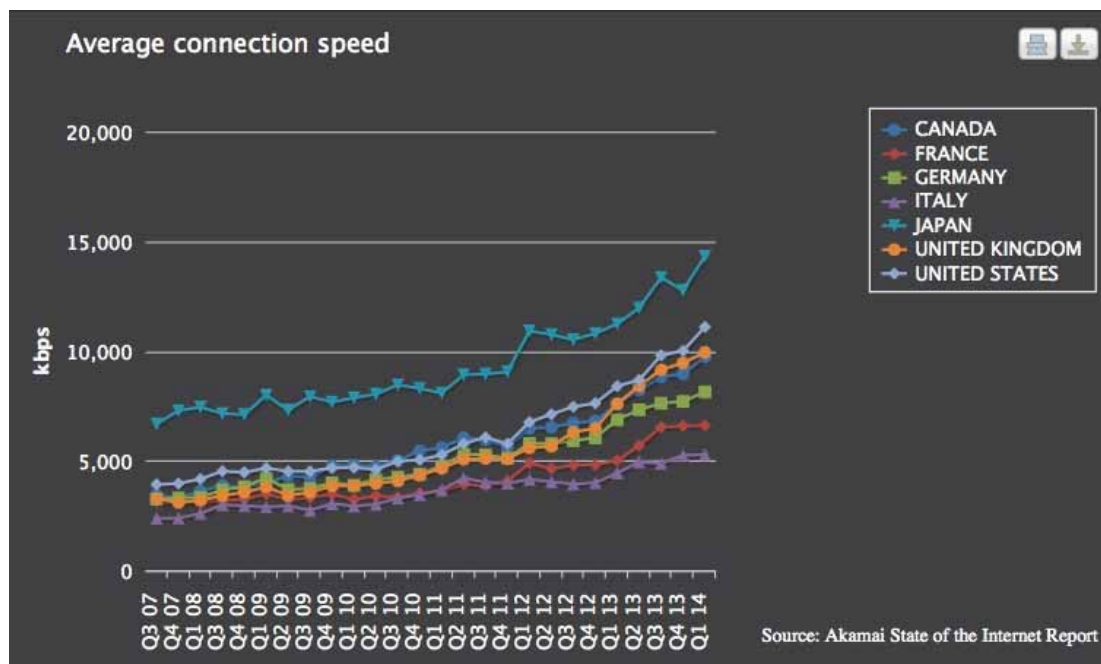


Figure 63: Browsing Experience in G7 Nations, 2007-14. Source: Akamai.¹²⁷

Because of variations in non-network factors, apparently substantial differences in network capacity don't translate to sharp difference in user experience.

HTTP Archive continually measures the average size of web pages. As of May 29, 2014, the average web page was 1,775 kilobytes.

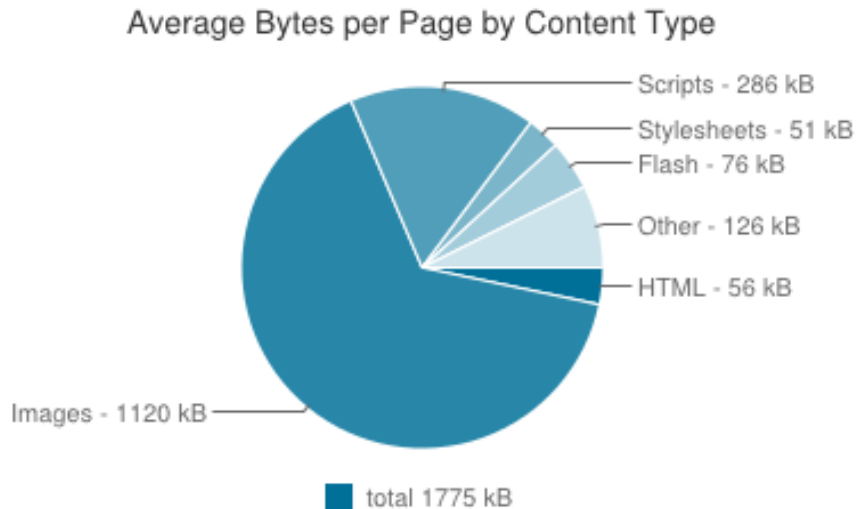


Figure 64: Average size of web pages, May 15, 2014. Source: HTTP Archive.¹²⁸

Browsers download from multiple TCP virtual circuits at the same time, so the fact that America's ACS is 10 Mbps does not mean that the load time for a web page can be calculated by dividing page size by 10 Mbps; rather, page load time is more closely estimated by the Average Peak Connection Speed, reduced by a factor that accounts for IP address sharing and network congestion. The following table estimates web page load time by reducing Average Peak Connection Speed by a "degradation factor" calculated from the ratio of ACS with APCS in each nation.

While web browsers use multiple connections at the same time, the aggregate bandwidth of these connections cannot exceed network capacity, and web pages are not always loaded over otherwise idle networks. The decay factor is similar in concept to the "promise gap" measured by the SamKnows tests, but it's a ratio of mean to peak speed in the real world rather than a ratio of measured to advertised network capacity.

If the user experience of web browsing were completely determined by network performance, pages would load nine hundredths of a second faster in Japan than in the U. S., but Japan had to build a nationwide fiber optic network (in addition to its DSL and cable networks) to achieve this benefit.¹²⁹ Users don't see web pages load this fast in the real world because server performance has a greater influence that most realize. Server delays reduce page load times by two to ten times the delay caused by the network in real measurements.

	ACS	APCS	Decay	Minimum Load Time	Typical Load Time
Japan	12.8	53.7	0.21	0.28	0.34
United States	10.0	43.7	0.22	0.36	0.43
United Kingdom	9.5	43.5	0.23	0.37	0.46
Canada	9.0	40.5	0.23	0.4	0.49
Germany	7.7	35.8	0.23	0.46	0.57
France	6.6	26.7	0.2	0.54	0.65
Italy	5.3	21.6	0.21	0.68	0.82

Figure 65: G7 Web Speed and Page Load Time. Source: HTTP Archive, Akamai, calculation.¹³⁰

The speed difference between Japan and the U. S. on the one hand and France and Italy on the other is somewhat more evident: web pages can load in half the time in the speediest G7 nations as they can in the laggards. This difference is perceptible, but not truly significant; Robert Miller's canonical human factors goal of one to five second response time for non-trivial interactive requests is met in all nations, even slowpokes France and Italy; and Miller's "instantaneous" threshold of two tenths of second is met in none.¹³¹ For all the public policy hand wringing over network performance, clients and servers primarily shape the web experience, not networks.

ii. Akamai Measurements of Actual Web Page Load Times

There is a considerable gap between the load times recorded by testing and the expected load times based on network performance. SamKnows records web page load times on the order of one second, but Akamai records times on the order of several seconds.¹³²

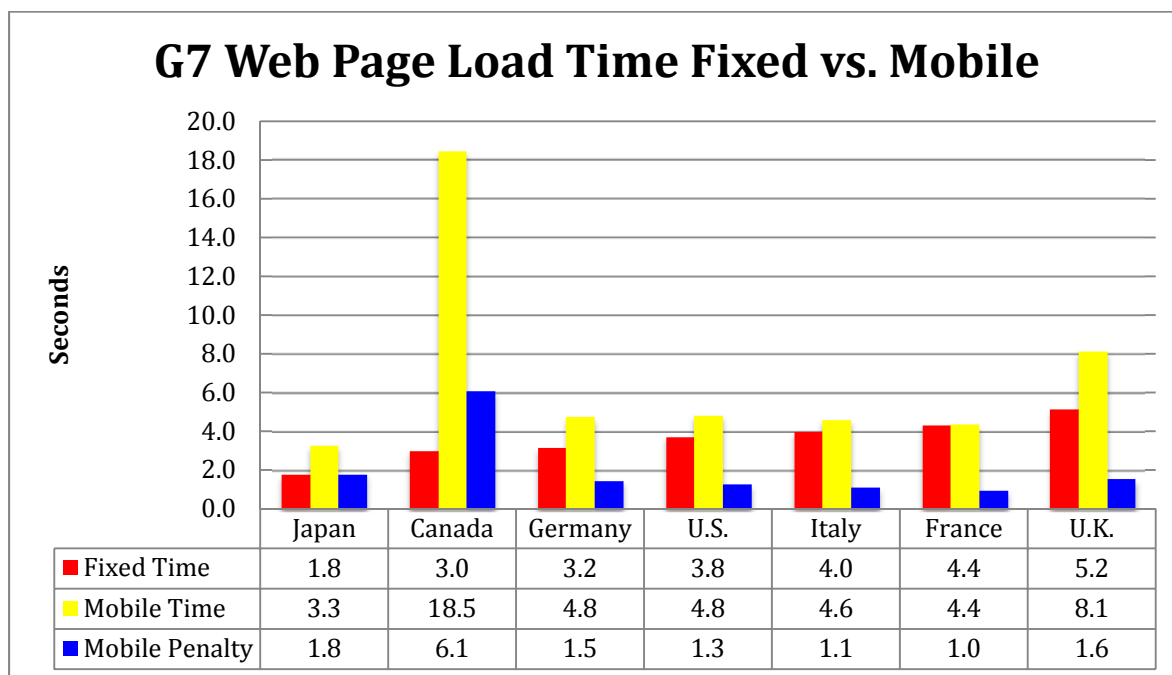


Figure 66: G7 Web Page Load Time by Network Type. Source: Akamai¹³³

Consequently, web page load time data can be used for illustrative purposes but not for comparative ones. It's interesting that mobile load times in France are the same for fixed and mobile networks, and that mobile load times are nearly as fast in Italy as wired ones. But this shouldn't be too surprising, given that Italy and France's wired networks are so poor.

F. Advertised Speed vs. Actual Speed

SamKnows entered the network testing space on the strength of a study commissioned by Ofcom that demonstrated a large gap between advertised and actual speeds on BT's network. The United States, the EU, Singapore, and several other nations now do SamKnows testing. The focus on narrowing the gap between advertised and actual rates has led to improvement in measured network speeds.

i. SamKnows Data for U. S. and Europe

SamKnows tests broadband connections in the United States and Europe to determine whether broadband suppliers deliver performance comparable to the "up to" speed they advertise. These tests are conducted by attached customized test agents - a combination of hardware and software - to selected subjects and running a suite of tests at various hours of the day and night. The SamKnows tests show that European broadband providers fail to deliver advertised speeds in almost all instances, while U. S. providers generally exceed advertised rates for satellite and fiber systems, meet them for cable, and fall short on DSL networks.

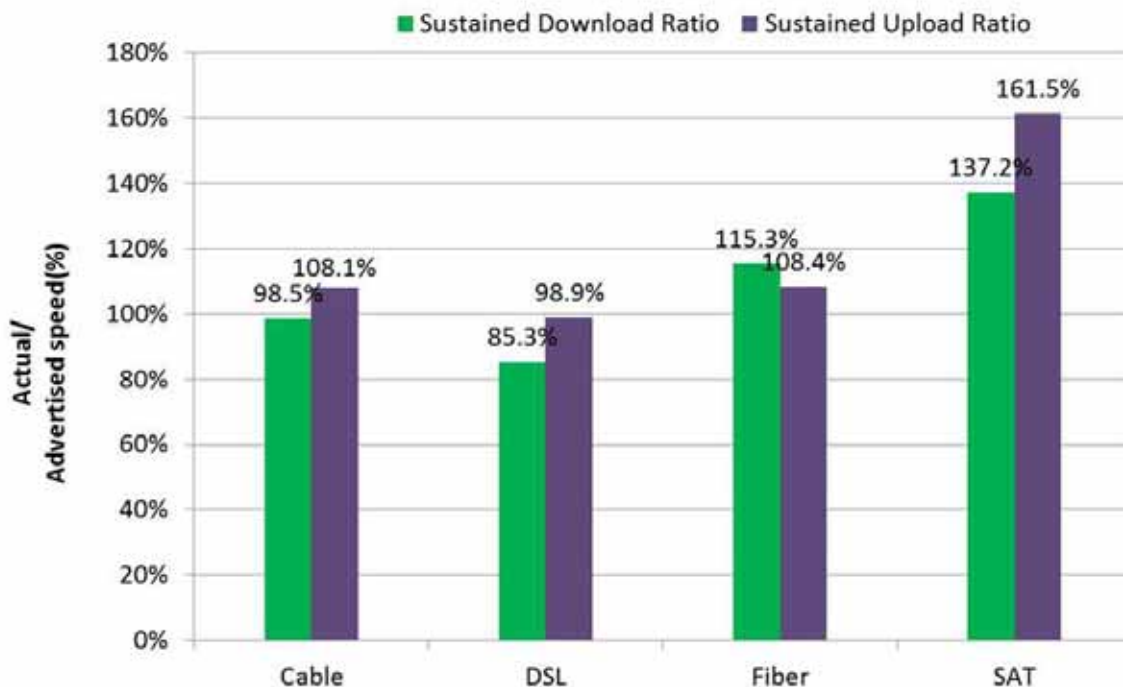


Figure 67: SamKnows Promise Index for U. S. by Technology, Sept. 2012. Source: FCC.¹³⁴

In March 2012, Europe as a whole generally fell short on its broadband promises for DSL and fiber, but generally delivered promised speeds over cable.

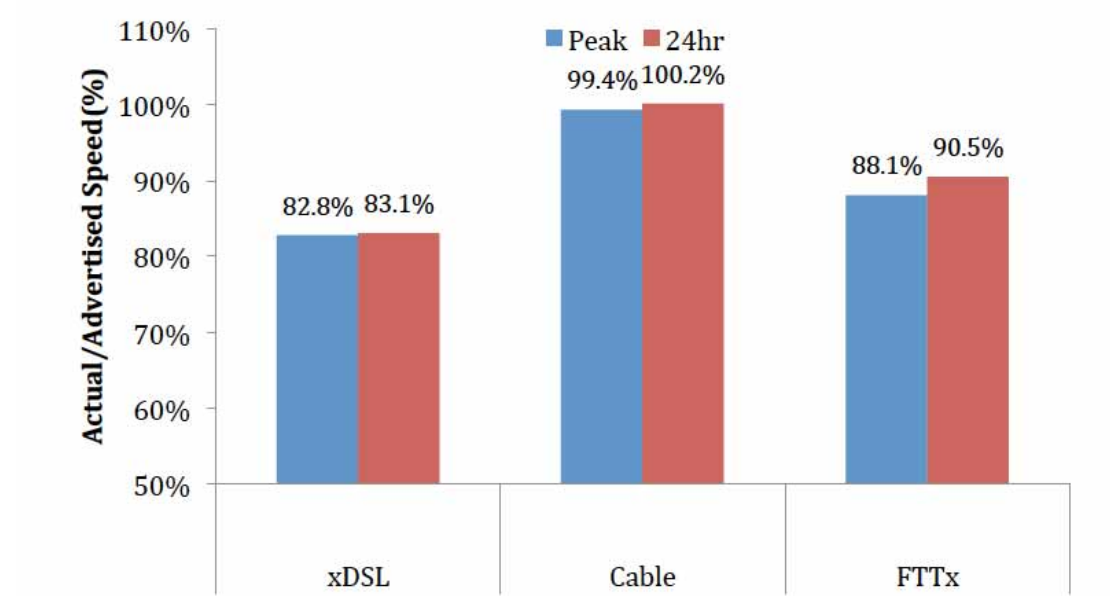


Figure EU.1-7: Actual Peak and 24-hour Period Upload Speed as a Percentage of Advertised Speed, split by technology (higher is better)

Figure 68: SamKnows Promise Index for Europe, March 2012. Source: EC.¹³⁵

A follow-up test in March 2013, showed modest improvement, but once again only cable met its advertising claims.

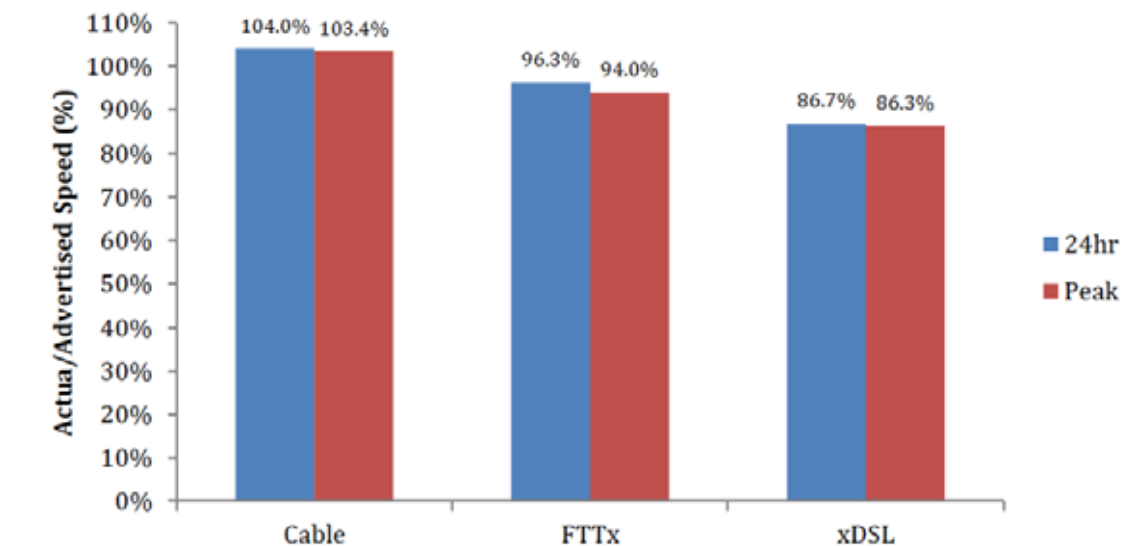


Figure EU.1-7: Actual Peak and 24-hour Period Upload Speed as a Percentage of Advertised Speed, by technology (higher is better)

Figure 69: SamKnows Promise Index for Europe, March 2013. Source: EC.¹³⁶

SamKnows tests have been run on the U. S. four times: in March 2011, April 2012, September 2012, and September 2013. In all instances, the U. S. surpassed Europe in

general and the European G7 members in particular by a wide margin in terms of delivering advertised speed.

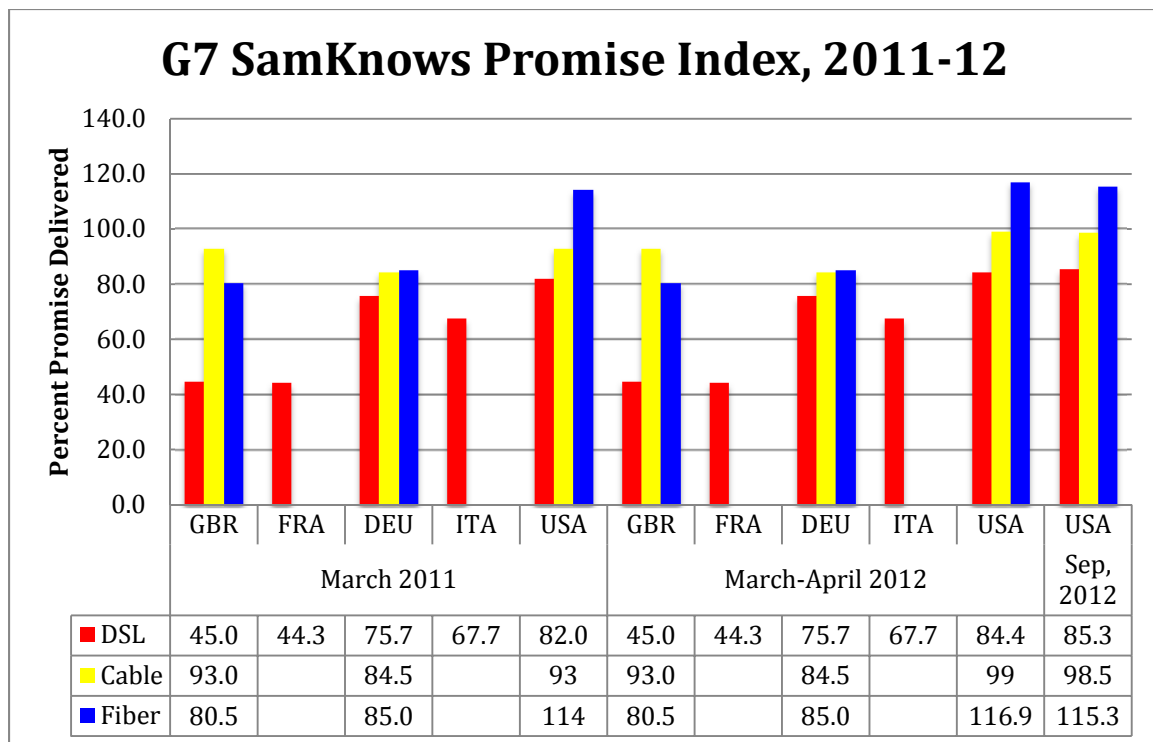


Figure 70: SamKnows Promise Index for G7 Countries. Source: EC¹³⁷, FCC¹³⁸.

The finding that the U. S. beats Europe in terms of advertising claims is not surprising given the nature of ADSL, but is peculiar for fiber. Most of Europe relies on ADSL, a technology whose performance is very sensitive to wire length; ADSL accounts for 78 percent of all active broadband connections in Europe. U. S. broadband is predominately cable; cable is also sensitive to distance, but much less so than ADSL. While fiber is the least sensitive to distance of any broadband technology, it falls short of claims in Europe. This is probably due to over-subscription of shared aggregation links. This is always a danger when firms strive for high last mile signaling rates without beefing up backhaul connections.

Rogers Cable of Canada voluntarily tested its network with SamKnows and reported that it exceeds advertising claims at all speed tiers.

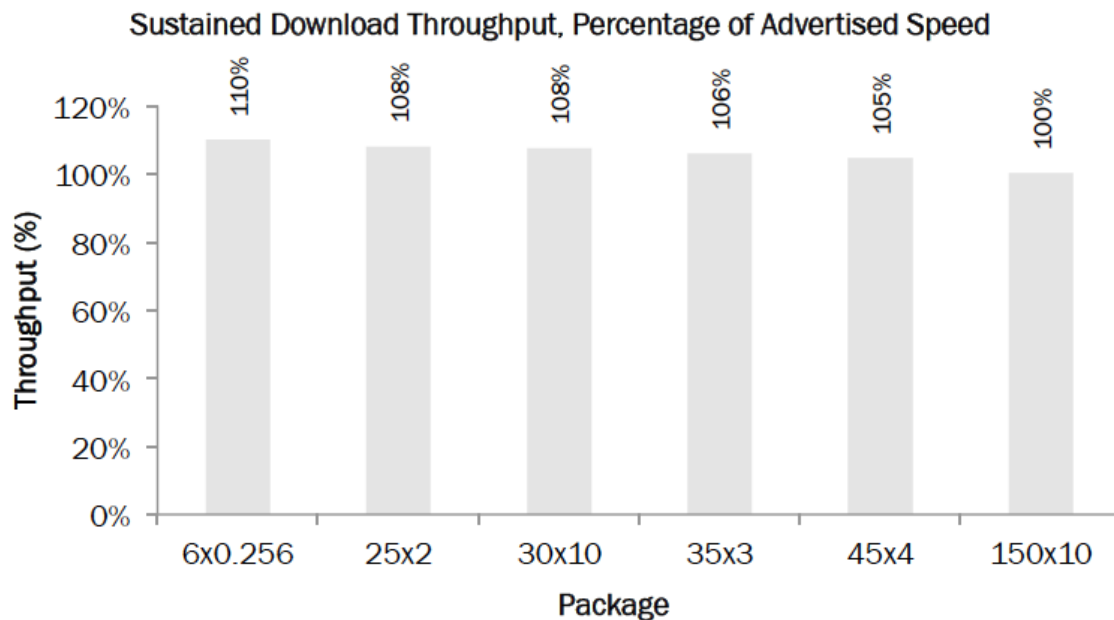


Figure 71: SamKnows testing of Rogers Cable Canada, May 2013. Source: Rogers Cable¹³⁹.

Rogers reports that it exceeds the U. S. Promise Index, and responsibly does not claim an average speed on the basis of SamKnows testing: “Rogers’ peak-hour download average of 106 percent of advertised speed exceeds the U. S. average of 97 percent.” This is the correct way to use SamKnows measurements. (Note: the U. S. now exceeds 100 percent of advertised rate across the board as well.¹⁴⁰)

ii. SamKnows as a Speed Survey: Using and Misusing the Data

Europe undertook SamKnows testing in order to determine where its networks stood in relation to those in the U. S., just as the U. S. undertook testing in order to compare its networks to those in the U. K., the first nation to publish SamKnows data. European policy makers were not happy with the results, so they tried to make lemons into lemonade by representing SamKnows as a test of actual network capacity rather than a test of advertising claims.

Network speed tests, for all their technical complexity, are surveys, fundamentally no different from any other survey in the sense that their validity depends absolutely on beginning with a representative sample of the population. SamKnows employs specialized equipment, the White Box, for testing. The White Box is a precise test instrument for networks in a particular capacity range, but its utility for conducting capacity surveys is entirely dependent on its distribution.

The U. S. and Europe gave SamKnows different directions regarding the distribution of White Boxes. The U. S. wanted to test each speed tier of each major ISP, so it required a more or less equal distribution according to that objective. Europe wanted to conduct testing by nation and technology, so it intended to adopt a distribution strategy that mirrored ISP market shares.

Europe did not distribute White Boxes according to the subscription ratios by technology reported by OECD, however. In fact, it oversampled cable and fiber and under-sampled DSL. This choice artificially elevates national scores.

SamKnows and the FCC made an additional choice in the U. S. that undermined the accuracy of SamKnows as a national speed test: it chose not to measure speeds above 75 Mbps. The FCC admits this:

*"In this report for the first time we tested download speeds as high as 75 Mbps (megabits per second), and we know that even higher rates are being offered by service providers to their customers."*¹⁴¹

Therefore, broadband services running at 100 Mbps and higher in the U. S. – such as the high end services provided by Comcast, Verizon, Google, and other gigabit networks – were entirely excluded from the U. S. sample. According to the National Broadband Map, broadband services with download capacities of 100 Mbps and above are available to 58.2 percent of American households and to 26.3 percent of rural American households. These services are not widely adopted, nor is their adoption measured, but it's not unreasonable to suppose that as many as 10 percent of U. S. broadband subscriptions are for speeds of 100 Mbps or more, with as much as a quarter of that for gigabit services. Given the imputed SamKnows national average for U. S. cable of 18.2 Mbps per second, a more complete sample would significantly raise the national average.

This is particularly troublesome given the market positioning of cable modem services in Europe. Cable modem in the U. K. is scarcely available at the capacity ranges SamKnows measures in the U. S.; U. K. cable monopolist Virgin Media's plans range from 50 Mbps to 152 Mbps. Consequently, it's not reasonable to compare U. S. SamKnows measurements to those in Europe despite the EC's claims to the contrary.¹⁴²

Ofcom, the U. K. regulator that has more experience with SamKnows than anyone else, recognizes that SamKnows is not a proper national or regional survey:

*"The prevalence of lower speed products in the U. S. has resulted in lower average speeds by technology in the U. S. than in Europe. SamKnows has conducted research on the performance of broadband in the EU and in the U. S. and finds that average speeds for ADSL broadband, cable broadband and fibre broadband are higher across European Union countries. However, higher cable take-up in the U. S. means that it is likely that average broadband speeds across all technologies are higher than in Europe."*¹⁴³

The FCC also acknowledges that SamKnows is at best a rough survey of average national capacity:

*"...we found that, on average, customers subscribed to faster speed tiers in 2012 than in 2011. This is a result of both upgrades by ISPs to their network as well as some migration of consumers to higher speed services. To illustrate this shift, we computed the average speed offered by ISPs across all panelists in 2011 and 2012. Due to the manner in which panelists are chosen, this provides a rough correlation with average subscribed tiers within the United States for the participating ISPs during the testing period."*¹⁴⁴

[Note: emphasis added for clarity.]

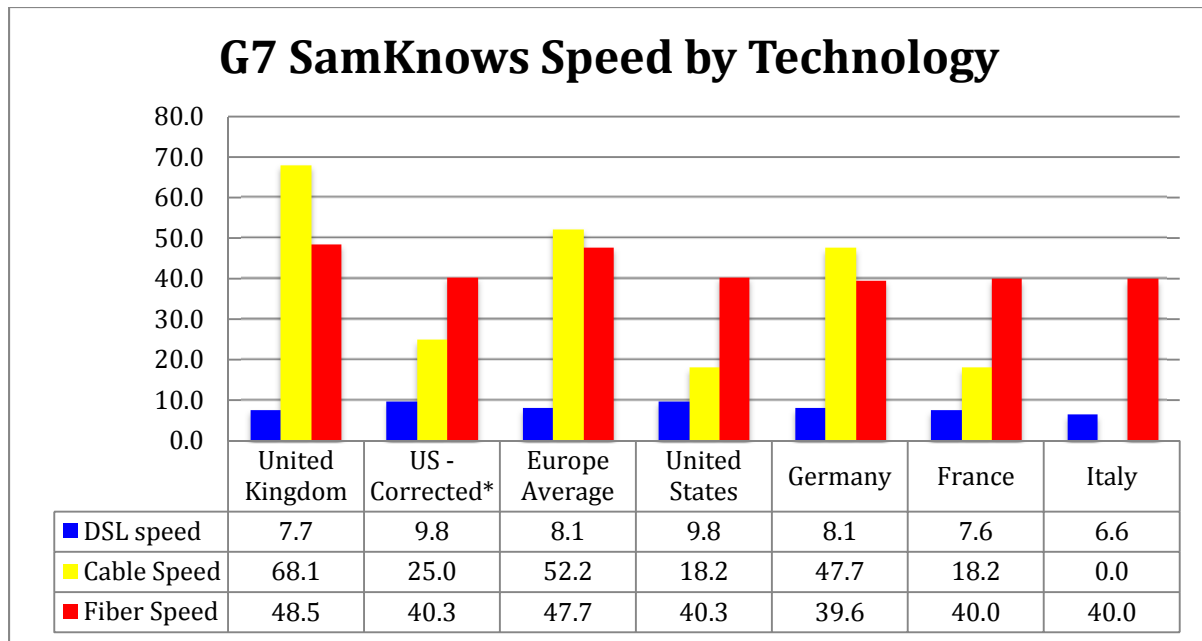


Figure 72: G7 SamKnows Speed by Technology. Source: OECD¹⁴⁵, EC¹⁴⁶, FCC¹⁴⁷.

Correcting the SamKnows data for both market share errors and under-sampling high speed plans in the U. S. still places the U. S. behind the U. K. in average download speed, but the relationship of speeds in the two nations is reasonably close in properly sampled surveys. In the 4th Quarter of 2013, Akamai ranked the U. S. tenth in average capacity at 43.7 Mbps and the U. K. 12th at 43.5 Mbps, for example. This correction also raises the U. S. above the European average. The U. S. ranks above all of Europe's G7 members except U. K. without correction.

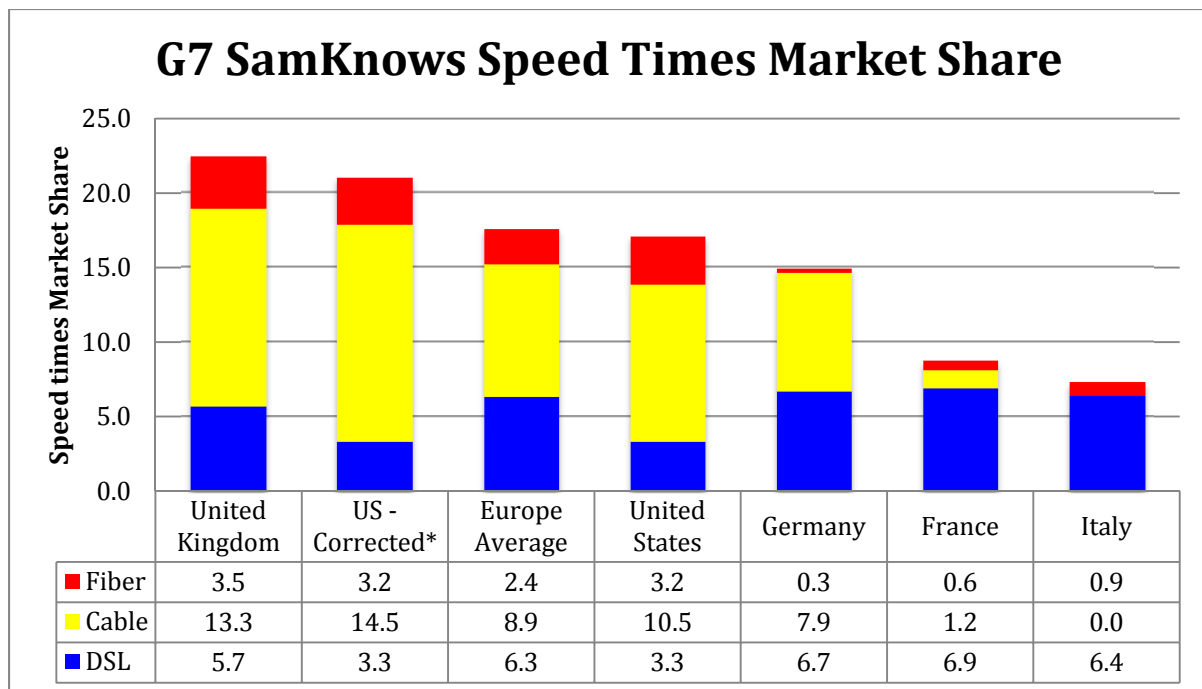


Figure 73: SamKnows G7 download speed times market share. Source: OECD¹⁴⁸, EC¹⁴⁹, FCC¹⁵⁰.

*SamKnows does not measure speeds higher than 75 Mbps in the U. S., and U. K. does not offer cable speeds less than 50 Mbps. Correction increases U. S. average from 18.18 to 25 Mbps to account for this arbitrary exclusion. Market share figures from OECD.

G. Network Utilization

Network speed is important for more than bragging rights, but networks are not worth much if they're not used. Researchers are beginning to realize that the single most important technical dimension of networks is the amount of traffic they carry. This dimension of network quality tells us when we're close to the right balance of price, speed, coverage, and digital readiness; we can't use networks heavily if they're not effectively usable. Increases in traffic load are also signals to network providers to upgrade speeds; the higher the signaling rate of a network, the more traffic it can carry.

Network utilization can be measured by ISPs and by crowd sourcing; in both cases, data has to be saved across system reboots and crashes, and cleared for each measurement period. On the basis of observations commissioned at Exchange Points, Cisco projects future utilization based on observed trends. These projections indicate that South Koreans are the heaviest users of Internet data, with the U. S. in second place and climbing. Canada and U. K., two other English-speaking nations with extensive bi-modal networks, follow the U. S. among G7 nations.

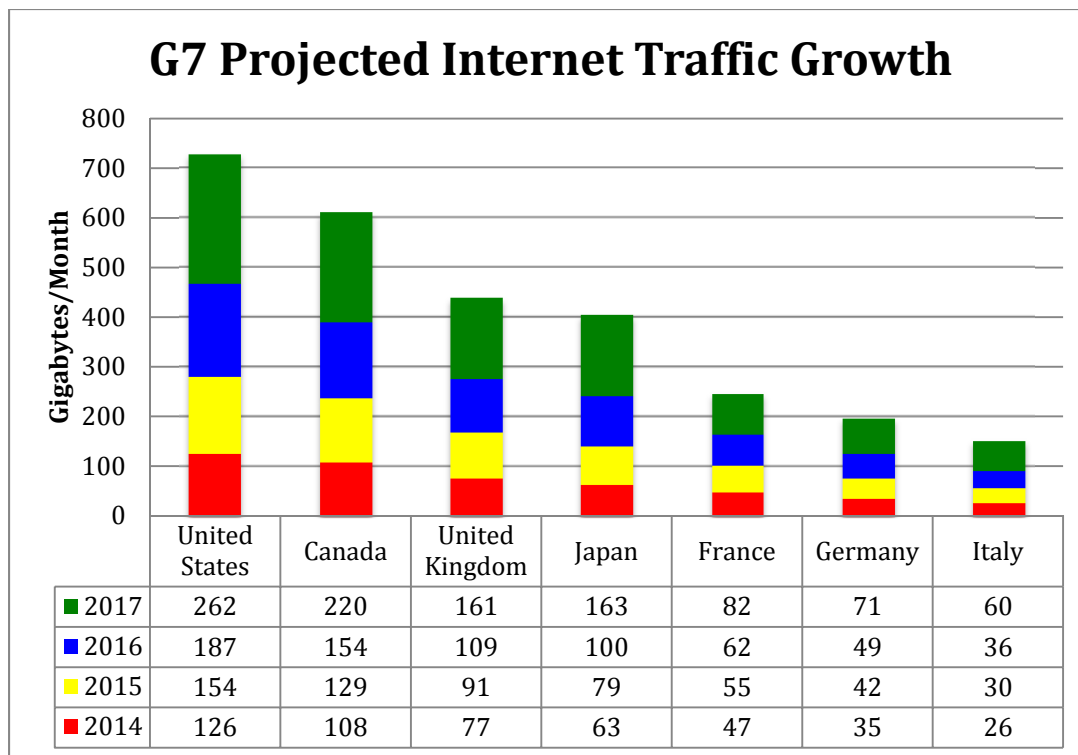


Figure 74: Projected Internet traffic in gigabytes per household per month. Sources: Cisco, World Bank¹⁵¹, and NationMaster¹⁵².

The nations in Continental Europe with slower wired networks take up the rear, but France appears to be keener on the Internet than Germany and Italy.

In terms of mobile traffic, the picture is quite different.

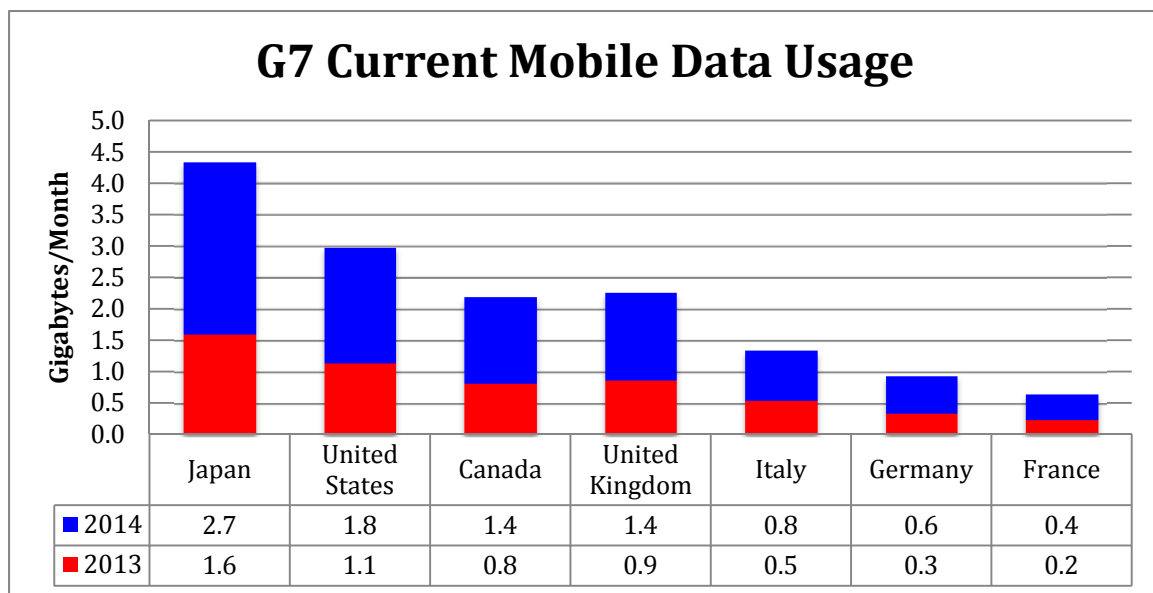


Figure 75: G7 estimated mobile data usage per household. Sources: Cisco, World Bank, and Nationmaster.

Cisco estimates that Japan has the highest mobile data usage; France, Germany and Italy have the lowest, and the U. S., Canada, and U. K. are in the middle. The gap between highest and lowest is 8:1, and larger spread than the data shows for wired connections, where the gap between the U. S. and Italy is 5:1.

It's hard to square this estimate with the data on smartphone adoption. For both wired and mobile, Cisco foresees the gap reducing, but not substantially.

5. Broadband Prices

Broadband prices are often surveyed through questionnaires and occasionally by reviewing advertising, but these methods are unlikely to yield meaningful results; for one example, see OECD's pricing criteria.¹⁵³ Advertising surveys can reveal significant results if they're extremely thorough; the survey of European and U. S. prices conducted by van Dijk Management Consultants for the EU in 2012 is a good example.

¹⁵⁴

A. Good and Bad Criteria

Pricing surveys often fall prey to a common faulty metric, comparison in terms of dollars per Mbps, which assumes that either the cost or the value of a 1000 Mbps connection is 100 times that of a 10 Mbps one; in the past, OECD Research was very fond of this way of measuring, but recently it has begun to examine performance tiers. It's reasonable to compare prices for a given level of speed in different locales, as the van Dijk study does, but less reasonable to compare the value of plans offering different speeds to each other. It's not clear what the following OECD graph is meant to measure, for example:

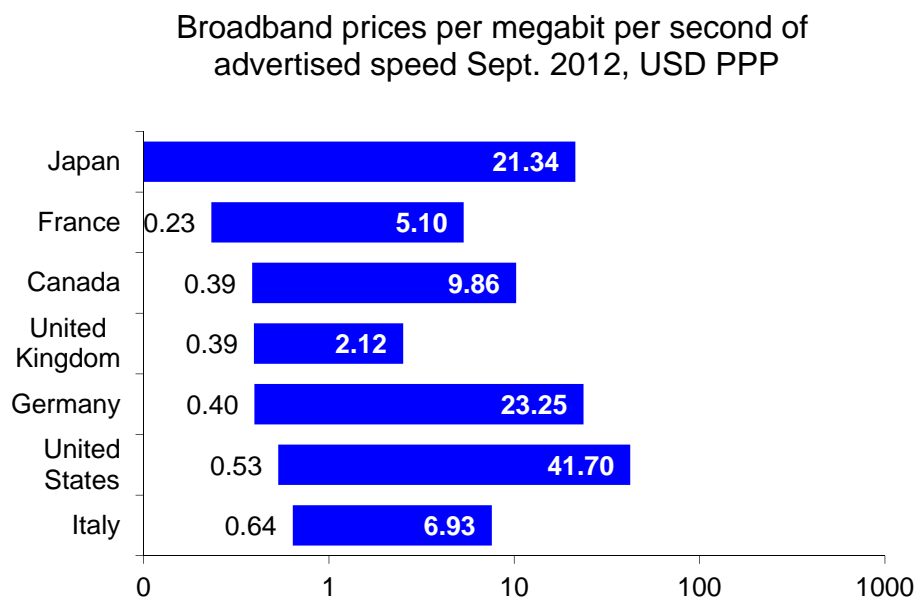


Figure 76: OECD Price Comparisons for G7 Nations. Source: OECD.

Cost and value are not linear functions of speed, and since these prices were collected some large ISPs in the U. S. have quadrupled speeds for middle tier service plans.¹⁵⁵ This places such plans beyond the speed ranges achievable in the EU without network

upgrades. Manufacturing volume drives technology costs, and today 1000 Mbps (gigabit) fiber transceivers are cheaper than 100 Mbps ones.

B. Errors of Selection and Omission

The advertising survey method is used by New America's *Cost of Connectivity* report as well, a report that compares the prices of Internet services in both urban and rural U. S. cities and towns to European capitals.¹⁵⁶

New America fails to select comparable bundles, comparing 50 channel international bundles to 200 channel U. S. triple play plans, it omits content fees ("TV license fees") paid by international customers, and it omits subsidies received by U. S. municipal networks and over-the-top ISPs in Europe (below-cost access to incumbent lines is effectively a subsidy). When content fees are included, it becomes apparent that the actual cost of connectivity is not as high in the U. S. as we've been lead to believe.

City	ISP	Subsidized?	NAF Price	License Fee	Price with License Fee	Download Speed	200 Channel US Content?
Paris	Free	Yes	\$35	\$15	\$50	28	No
Paris	SFR	Yes	\$35	\$15	\$50	25	No
Paris	Bouygues Telecom	Yes	\$37	\$15	\$52	20	No
Paris	Darty	Yes	\$37	\$15	\$52	20	No
Bristol, VA	BVU	Yes	\$55	\$0	\$55	6	
Berlin	Tele-Columbus	Yes	\$34	\$25	\$58	16	No
London	Sky	Yes	\$38	\$20	\$58	16	No
Berlin	Kabel Deutschland	Yes	\$36	\$25	\$61	32	No
Lafayette, LA	LUS	Yes	\$65	\$0	\$65	15	
Washington, DC	RCN	No	\$68	\$0	\$68	25	Yes
Los Angeles, CA	Verizon	No	\$70	\$0	\$70	15	Yes
New York, NY	Verizon	No	\$70	\$0	\$70	15	Yes
New York, NY	Time Warner Cable	No	\$75	\$0	\$75	15	Yes
Lafayette, LA	AT&T	Yes	\$79	\$0	\$79	6	Yes
Los Angeles, CA	Time Warner Cable	No	\$80	\$0	\$80	15	Yes
Washington, DC	DSL	No	\$80	\$0	\$80	15	Yes
Chattanooga, TN	EPB	Yes	\$82	\$0	\$82	100	
New York, NY	RCN	No	\$90	\$0	\$90	25	Yes

San Francisco, CA	Comcast	No	\$99	\$0	\$99	25	Yes
Bristol, VA	Charter	No	\$100	\$0	\$100	30	Yes
Kansas City, KS	Time Warner Cable	No	\$100	\$0	\$100	15	Yes
Los Angeles, CA	AT&T U-Verse	No	\$109	\$0	\$109	18	Yes
Kansas City, MO	Time Warner Cable	No	\$112	\$0	\$112	10	Yes
Washington, DC	Comcast	No	\$113	\$0	\$113	20	Yes
Lafayette, LA	Cox	No	\$121	\$0	\$121	5	Yes
Chattanooga, TN	AT&T	No	\$133	\$0	\$133	6	Yes
San Francisco, CA	Astound	No	\$134	\$0	\$134	15	
Chattanooga, TN	Comcast	No	\$151	\$0	\$151	20	Yes

Figure 77: Triple-Play prices in some G7 cities and towns, including content fees. Source: New America¹⁵⁷, Layton¹⁵⁸

Leaving aside New America's omissions, the advertising survey method can't capture representative prices paid by real consumers because current advertising doesn't include prices paid under old contracts.¹⁵⁹ There is also no guarantee that prices obtained from surveyed ads are apportioned correctly across the user population.

C. Comprehensive Advertising Surveys

The van Dijk report previously mentioned confirms findings by the Berkman Center and ITU that U. S. broadband prices tend to be lower than those in Europe for low speeds ("entry level") and higher for higher speeds.¹⁶⁰

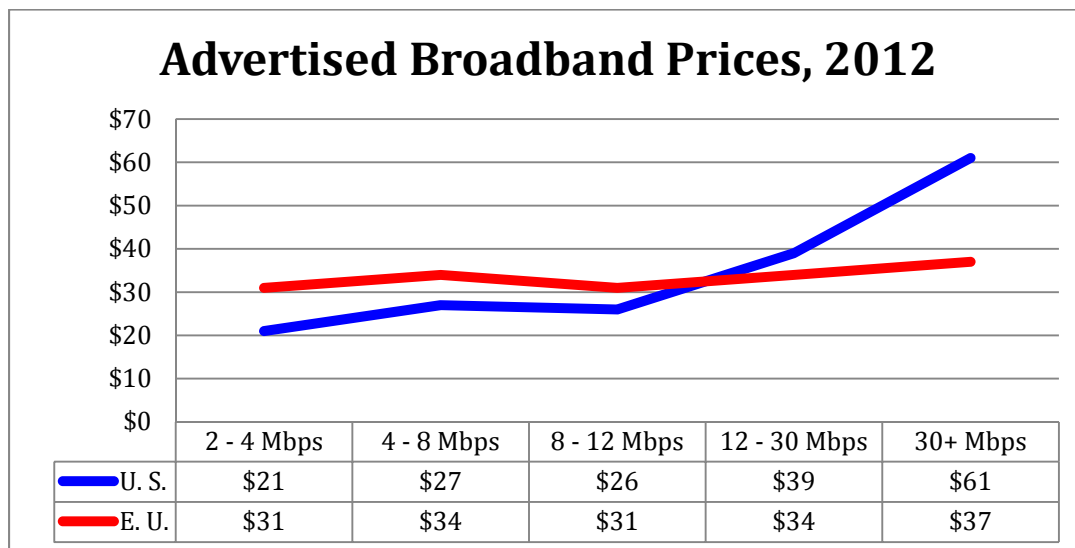


Figure 78: Broadband prices by speed, U. S. and EU 2012. Source: van Dijk¹⁶¹

This report doesn't cover Canada and Japan, however.

D. Consumer Surveys

Consumer surveys are a reasonable approach as long as they don't ask detailed questions about upload and download speeds; Point Topic and others engage in this sort of research.

For all forms of broadband, Point Topic ranks all of the G7 below the global average of monthly subscription fees paid for standalone broadband services. Point Topic rates the U. S. and Canada at the high end of the G7, France and Japan at the low end, and the rest of Europe in the middle. Point Topic does pricing surveys for the EU now, but their findings don't mesh very well with the OECD estimates of prices paid for standalone broadband; it's likely that Point Topic is more reliable.

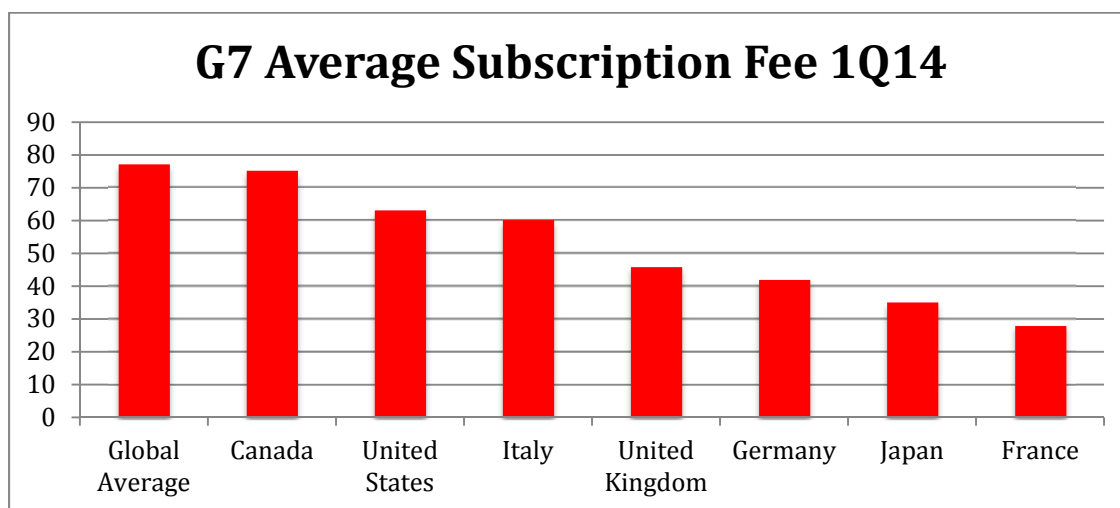


Figure 79: Average monthly broadband prices for standalone residential services in Q1 2014. Source: Point Topic.¹⁶²

Because of the variations in survey data, it's more prudent to establish prices paid on the basis of Average Revenue per User (ARPU) figures calculated by consultancies from financial data where they are available; at the moment, we can only get ARPU from financial statements for mobile broadband, so it's necessary to rely on survey data for wired broadband. Mobile ARPU data are taken from Infonetics Research¹⁶³ and the Bank of America/Merrill Lynch Wireless Matrix¹⁶⁴. Wired prices come from Point Topic surveys.¹⁶⁵

E. Perceived Value

Boston Consulting Group estimates the cost and perceived value of Internet use in five of the G7 nations. Curiously, their analysis generally places the highest value on the use of the Internet in nations with the least intensity of Internet use, the lowest contribution of the Internet economy to GDP, and the highest prices. In BCG's analysis, email, search, and banking are the most valuable uses of the Internet.

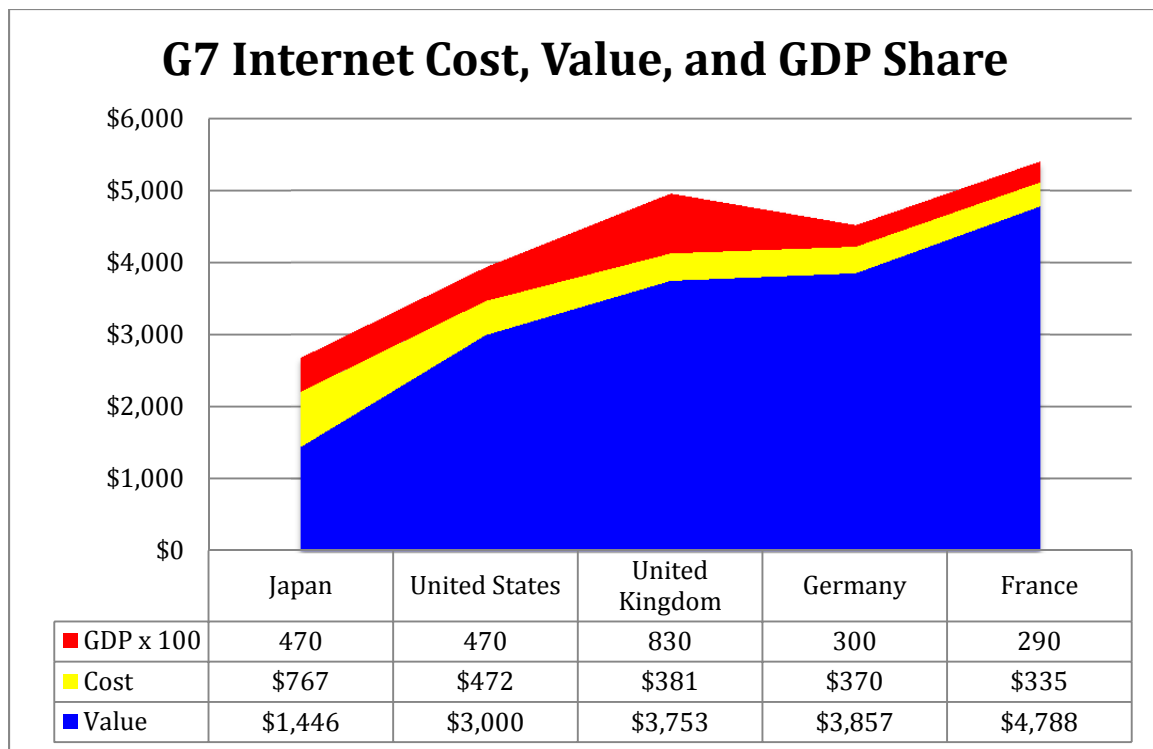


Figure 80: G7 Internet Cost, Perceived Value, and Contribution to GDP. Source: Boston Consulting Group¹⁶⁶

6. Consumer Value

In attempting to calculate broadband value, many analysts construct “value indices” on the basis of dollars per Mbps capacity.¹⁶⁷ This method is inappropriate because it assumes the costs of building and operating networks are the same in all locales and that value increases linearly with capacity.

It’s useful to think of consumer value as a ratio of service quality to consumer price minus the underlying provider cost of providing the service; this doesn’t capture its utility to the user, but allows us to determine the extent to which providers may or may not be extracting excessive surplus. This form of analysis is simply an alternative to the “dollars per megabit” over-simplification; it is not a substitute for the economics of consumer surplus.

Hence, cost factors such as distance, density, and traffic volume must be considered when assessing value, and capacity evaluations must recognize diminishing returns for speeds above the utility threshold.¹⁶⁸ Internet transit services are priced on the basis of volume and distance because these factors reflect real costs of service; beyond the point of being able to use all the applications the user wishes to use, capacity has little value.¹⁶⁹

A. Distance

Distance plays a role in the cost of transceivers, power, repeaters, switches, cable, installation, and maintenance. Some costs are linear functions of distance, such as

cable, installation, and maintenance, and others are step functions. But all costs can be modeled as linear functions:

...looking only at specific instances of connectivity, the cost [of electronics] is a step function of distance (e.g., equipment manufacturers sell several classes of optical transceivers, where each more powerful transceiver able to reach longer distances costs progressively more than less powerful transceivers). Over a large set of links, we can model cost as a smooth function of distance.¹⁷⁰

There is no public data available regarding miles-per-connection in broadband networks, so we can only model transport distance very roughly according to population distribution and IX density.

B. Volume

Usage volume is also a key factor in transit pricing:

The Internet Transit service is typically a metered service outside of the residential market. The unit price for Internet Transit services varies widely, but the service itself is typically priced on a per-megabit-per-second (Mbps) basis, metered using the 95th percentile traffic sampling technique.

Definition: The 95th Percentile Measurement Method (also called 95/5) identifies a single measurement (the 95th percentile 5-minute sample for the month) to determine the transit service volume for monthly transit fee calculation.¹⁷¹

Transit prices are set by distance and a per-megabit-per-second measurement of **actual volume** used, not on the Mbps of raw link capacity used in naïve value comparisons.¹⁷²

C. Capacity

Residential broadband services are typically sold on the basis of raw link capacity, although some carriers are experimenting with pricing models that comprehend usage volume. Raw link capacity – typically called “speed” – is a function of the last generational technology upgrade, such as from DOCSIS 2 (with a peak rate ceiling of 40 Mbps) to DOCSIS 3 (with a peak rate ceiling of 160 Mbps in most cases).

One portion of the residential broadband bill reflects upgrade costs, another portion reflects transit costs (volume and distance), yet another portion reflects internal carriage and interconnection costs with other networks, and the rest goes to taxes, fees, and profit.

Internet service providers collect fees from consumers, and also may collect subsidies from taxpayers, fees from third party content providers (such as “paid peering” fees) and in some cases, additional de facto subsidies in situations where inside wiring is installed and maintained by landlords at their expense. A survey of relative transit prices around the world reports that they’re similar in North America and Western Europe, higher in Asia and highest in Australia.¹⁷³

D. Broadband Value Equation

Consequently, broadband value to the consumer is a function of the quality of the broadband service divided by the profit retained by the service provider. One way to measure this is to divide the consumer price by the line rate in dollars per megabit per second, for example, but that measure is so crude that it leaves most of the significant usage and cost factors out the analysis.

A better way to define the function is to divide bandwidth by service provider profit. In transit pricing, bandwidth is measured by usage as well as capacity, so I use that convention here: bandwidth is line capacity times the actual volume of data transported.

$$\text{Value} = \frac{\text{provider profit}}{\text{average download speed} \times \text{average data volume}}$$

Profit is simply revenue minus expenses, calculated in two ways: as net income (revenue minus opex) and as revenue minus investment. Instead of “dollars or revenue per megabit”, this method gives us “dollars of profit per unit of bandwidth”, where “bandwidth” is the product of speed, volume of data, and distance. This is not conventional analysis, but it should be.

E. International Comparisons

Unfortunately, corporate and market structures make it difficult to isolate profitability in very precise terms at the national level because so many European and Asian telecom firms are multi-nationals who do not report expenses and earnings at the national level. For firms that operate in multiple nations, reported profits will be applied to each nation in the G7 in which they have a presence. One of the datasets apportions revenue and expenses by nation (Bank of America Merrill Lynch) and the other (Infonetics) doesn't; so the analysis is more precise for mobile services than for wired ones.

F. Wired Networks

The Infonetics database includes all carriers, wired, mobile, satellite, and diversified firms that provide multiple services. While it separates capex by wired and mobile lines of business, it does not separate revenue and opex in the same way. Therefore, revenue and opex have been allocated to the wired and wireless lines of business in proportion to the ratio of wired to wireless capex. This allocation introduces significant error that can only be corrected with better data on the actual revenue and opex by line of business. The BAML database properly allocates, but it only covers the mobile sector. Consequently, the wired financial analysis should be taken as demonstration of a method of comparison rather than an empirically sound analysis.

The diversified category includes such firms as AT&T and Verizon in the U. S., Rogers and Bell Canada in Canada, Orange and SFR in France, Deutsche Telekom in Germany, Telecom Italia in Italy, and NTT Group, KDDI, and Softbank in Japan.

The wired-only category mainly includes cable companies in the U. S., Canada, Germany, Japan, and the U. K., Tiscali and Fastweb in Italy, and BT and KCOM in the U. K.

i. Revenue

The wired network data does not allow us to evaluate revenue across nations, only by firm. Therefore I hazard no guess as to the proportion of GDP spent on wired broadband in any particular country, but I acknowledge this is a vital piece of information that needs to be gathered for future analysis of wired networks. Fortunately, it is available for mobile networks.

ii. Opex

Subtracting opex from revenue yields a simplified version of net income. Opex is extremely high in Japan and U. K., where the sample is dominated by former government monopolies NTT and BT. The U. S. also has high opex because of service and market conditions; Italy and Canada are more operationally efficient, and France and Germany define the norm.

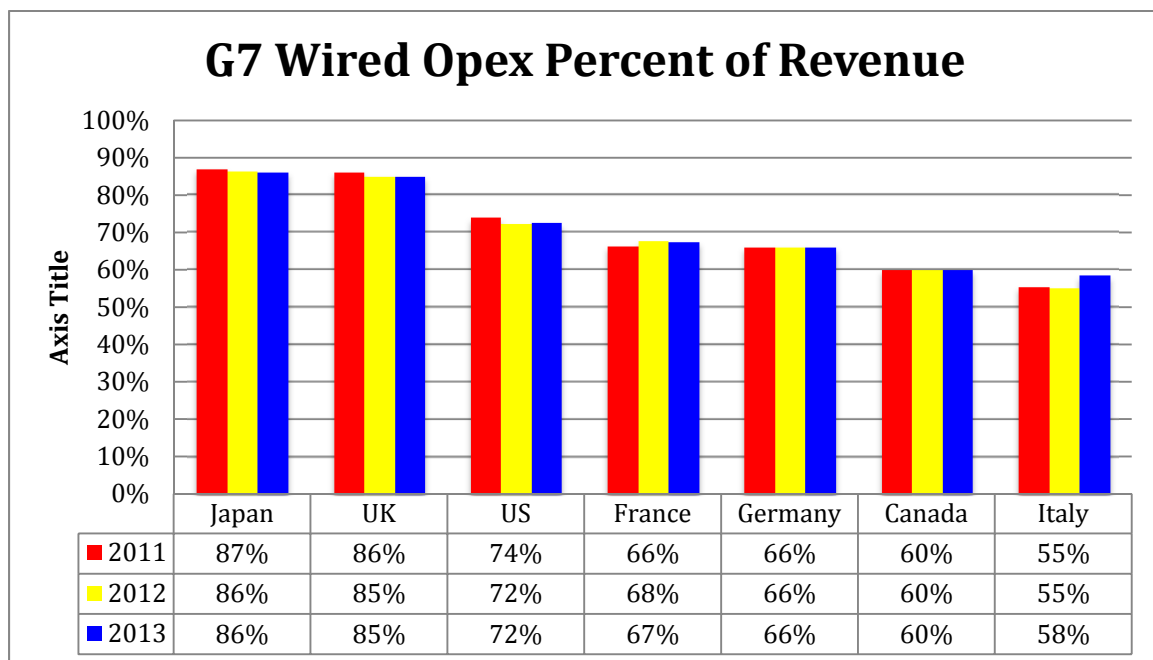


Figure 81: G7 Wired Opex Percent of Revenue. Source: Infonetics and author's analysis.

iii. Capex

Examination of capex as a percentage of net income by nation for wired broadband providers shows capex spending in Japan and U. K. in excess of income. In other words, the wired broadband firms in these countries are cash flow negative. The details show the big spenders are NTT and BT. We see the lowest capital spending in Germany and Canada, reasonably high capital spending in the U. S., France, and Italy.

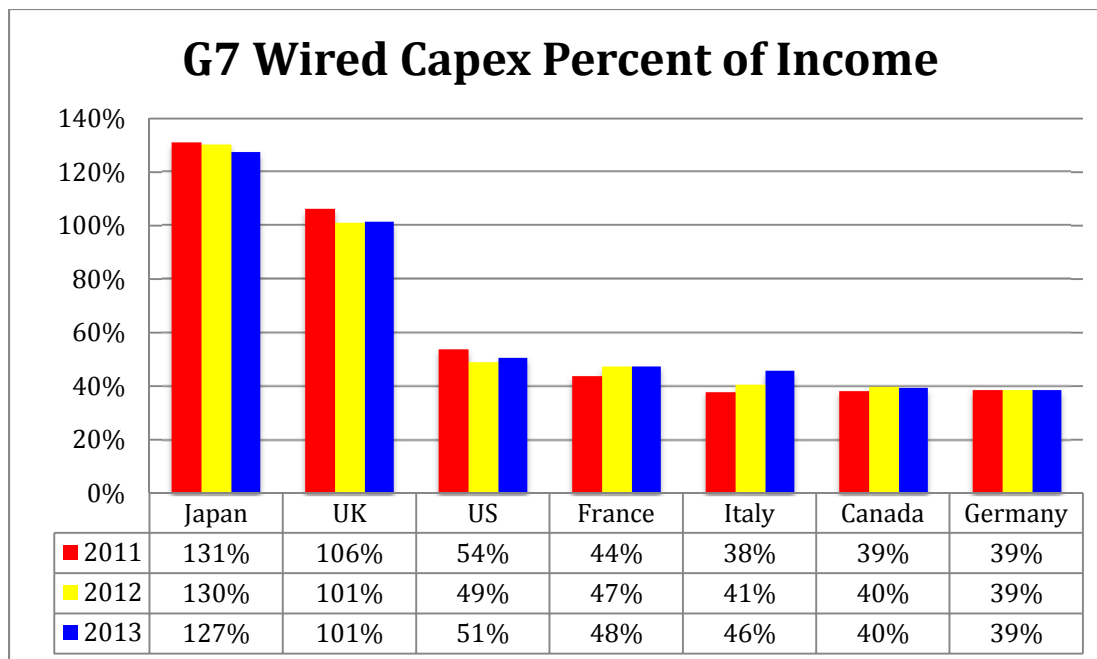


Figure 82: Capex as percent of income for G7 wired broadband firms. Source: Infonetics

Capex is motivated by different factors than opex: it reflects the desire to achieve growth, while opex reflects current capacity costs.

iv. Pre-tax Free Cash Flow

After we subtract capex from earnings, we arrive at another figure that expresses bottom line profitability, pre-tax free cash flow (net income is the more common measure). This is the term that represents money that can be distributed to share holders, spent on future acquisitions and paid to the tax authorities. If consumers are getting a raw deal, firms are likely to retain significant cash after covering expenses and funding future investments. The ideal value for this figure is subjective: it should neither be too high to encourage subscriptions nor too low to make the stock attractive. For firms that rely on debt financing, cash flow is negative, often for years at a time.

The highest levels of pre-tax free cash flow are found in Canada; the lowest levels are in the Japan and U. K. (where firms are cash flow negative,) and the U. S., Germany, France, and Italy are in the middle, ranging from 49 to 54 percent in 2013.

Generally speaking, Japan, U. K., and the U. S. provide the highest performing wired network connections, so it's not particularly surprising that these nations would have the least free cash. The data is not sufficiently precise for us to reach any particular policy conclusions, however.

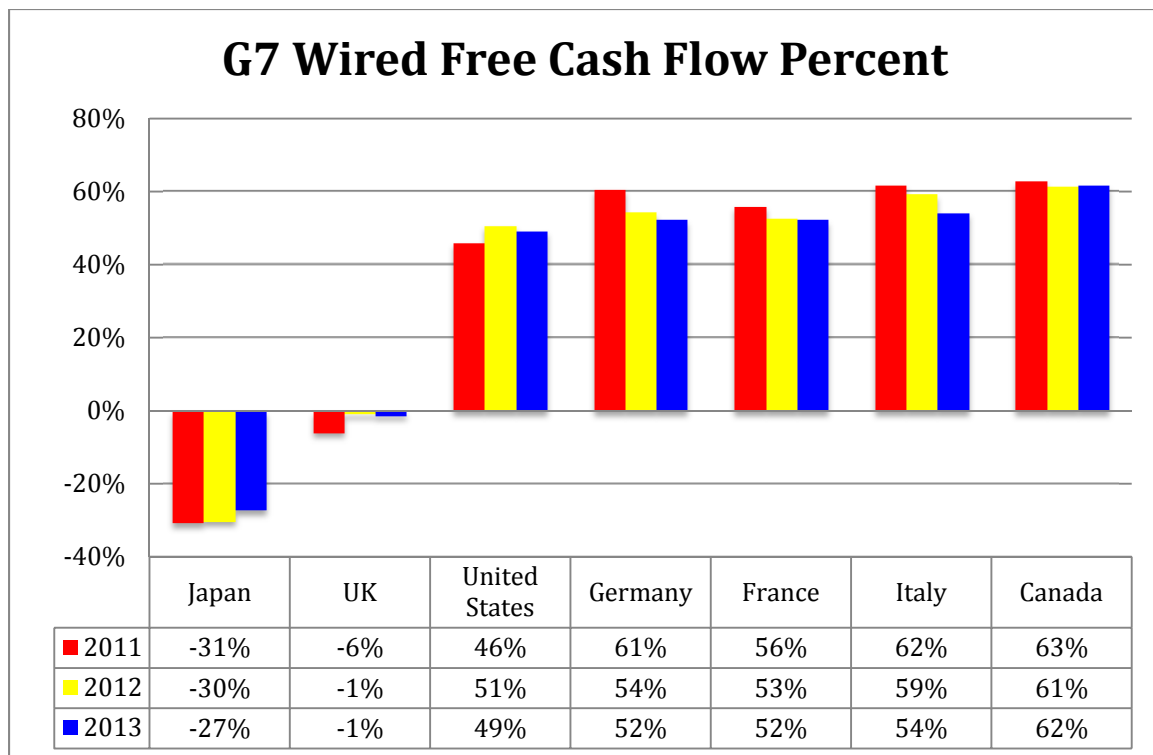


Figure 83: G7 wired broadband pre-tax free cash flow as percent of income. Source: Infonetics

v. Wired Network Consumer Value

It's reasonable to assess the consumer value of policy models by computing the price of bandwidth after correcting for the costs of providing it. We do this with reasonable precision for mobile networks because BAML Mobile Matrix has extracted the financial data on a national basis. For wired networks, the exercise is much more approximate because lines of business and national markets are not segregated in the Infonetics database.

The following exercise calculates carrier profit using the margin calculated from the Infonetics database by subtracting opex from revenue and dividing the remainder by revenue. It then multiplies margin by the revenue per household reported by Point Topic in order to get an average dollars of profit per household. Profit dollars per household is then divided by the product of capacity ("speed") and volume using Akamai's capacity estimate and Cisco's volume estimate to arrive at the consumer's price of bandwidth in dollars of profit.

This is a very approximate calculation because the margins calculated from the Infonetics data are unlikely to be completely accurate for France, Germany, and Italy because of multinational reporting. As each European nation is dominated by one carrier with substantial market power (SMP), the calculations are still likely to be meaningful, however.

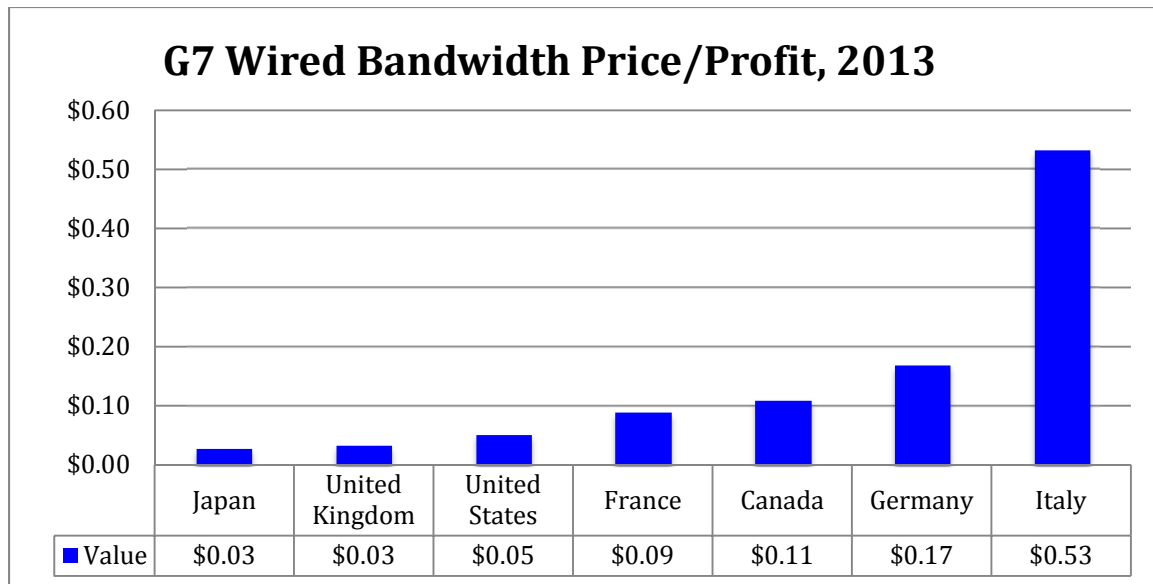


Figure 84: G7 Wired broadband end user bandwidth price in dollars of profit. Source: Infonetics, Point Topic, Akamai, Cisco.

It's also useful to examine bandwidth prices by profit after investment, calculated by dividing bandwidth by from Point Topic's revenue per household minus ITU's investment per household. As with the preceding analysis, this chart characterizes bandwidth as capacity times utilization. This analysis encounters a negative term in Italy, but positive terms in other nations.

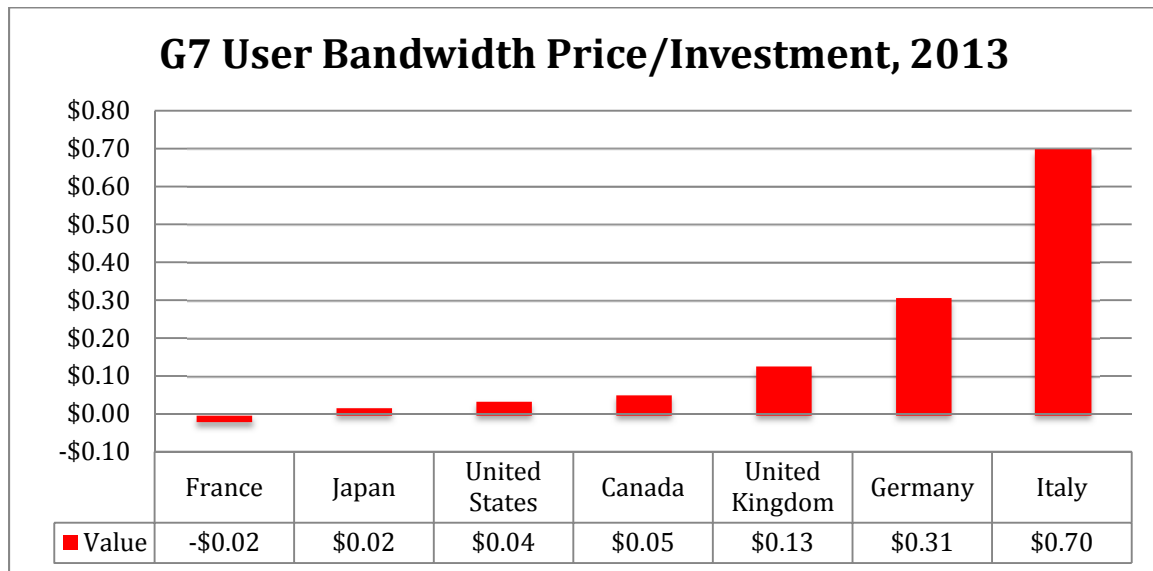


Figure 85: G7 End user bandwidth price after investment. Source: ITU, Point Topic, Akamai, Cisco.

G. Mobile Networks

Mobile networks have fundamentally different financial characteristics than wired ones because most mobile accounts are per-person and most wired accounts are per

household. Consequently, wired accounts serve an average of 2 - 2.5 people, while most mobile accounts serve one person or less.

The individual nature of mobile services makes them easier to compare across nations, but each nation features different cost and policy factors.

i. Revenue

Revenue for mobile services is best analyzed in terms of Average Revenue per User (ARPU) because mobile accounts are individual rather than per firm or per household. Mobile revenue data is available from multiple sources; Infonetics and Bank of America Wireless Matrix are the key sources for this section.

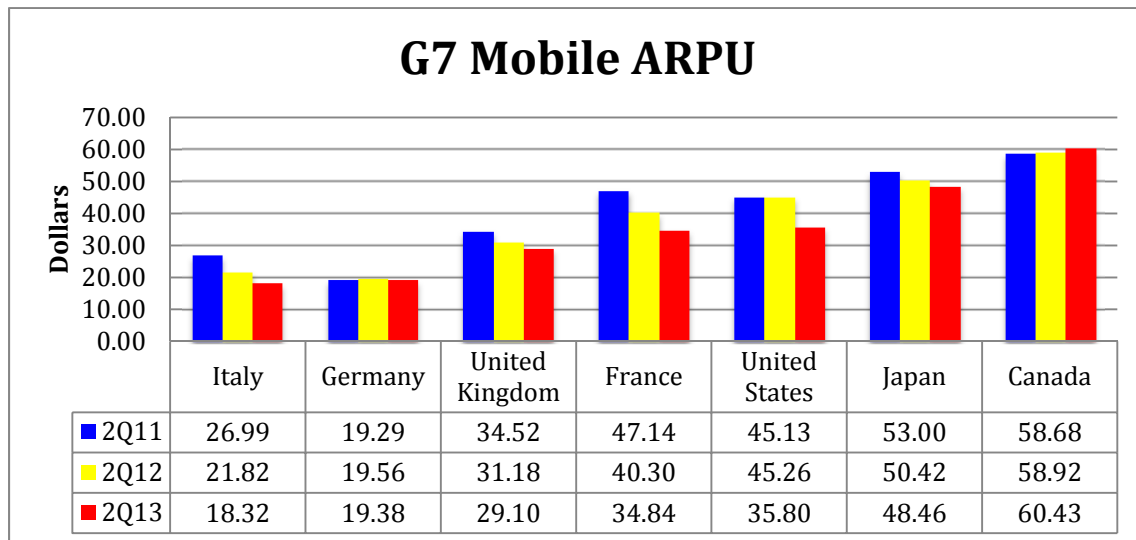


Figure 86: G7 Mobile Average Revenue per User. Source: Infonetics

In absolute terms, Infonetics estimates the highest ARPUs are found Canada and Japan, the lowest in Germany and Italy, with the middle encompassing the U. S., France, and the U. K. Switching to Wireless Matrix to index ARPU to GDP changes the ordering. By this analysis, Japan and the U. S. collect the highest mobile ARPUs, Germany and the U. K. collect the lowest, and Italy, Canada, and France are in the middle. The only nation that moves more than one place in this pivot is Canada, the nation with the second-highest GDP per capita in the G7.

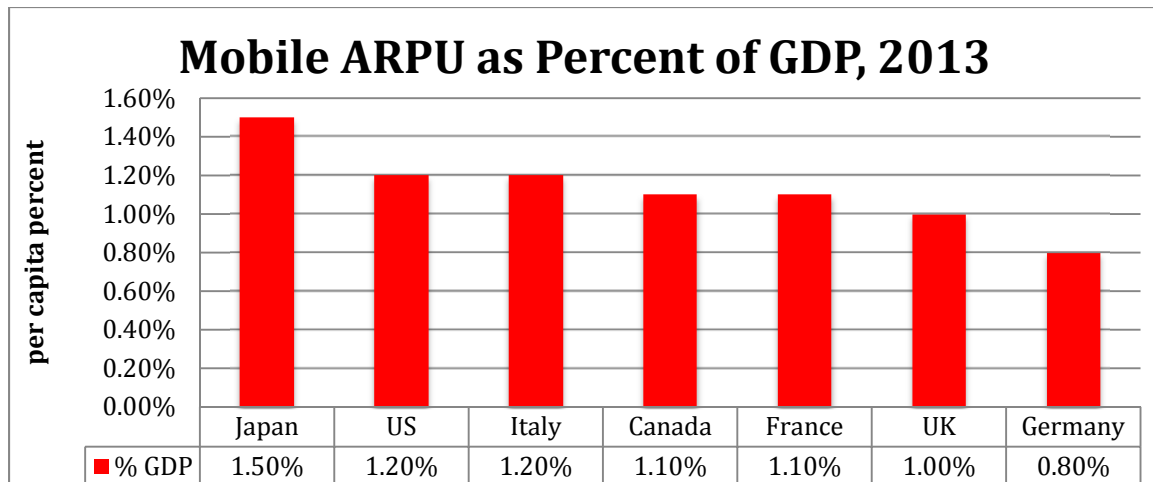


Figure 87: G7 Mobile ARPU as Percent of GDP. Source: Mobile Matrix.¹⁷⁴

Mobile revenue doesn't represent a uniform service across the G7, as some nations have more smartphone penetration than others, and voice minutes are radically different from nation to nation. The U. S. leads the G7 in the use of voice minutes, with an average of nearly a thousand minutes per month, while Japan averages less than hundred. In terms of ARPU from data, the highest levels are found in Japan; the lowest in France, Italy, and the U. S.; and U. K., Canada, and Germany are in the middle.

In terms of smartphone adoption, the U. S. leads the G7 with a 50 percent rate, followed closely by U. K. at 49 percent. Italy and Japan have the lowest adoption rates, contrary to Japan's image as a "gadget-happy" nation. Canada, France, and Germany are in the middle, waiting to see what all the fuss is about. With web pages now loading in France as fast over mobile networks as wired ones, the question should be answered soon.

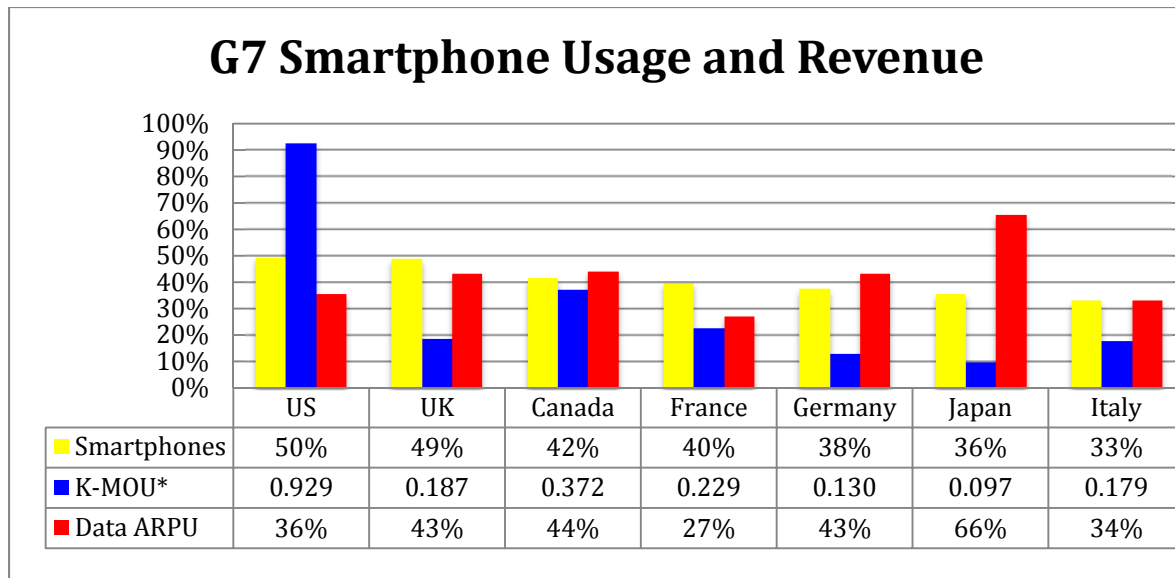


Figure 88: G7 Smartphone Adoption and Use. Source: Mobile Matrix.¹⁷⁵

ii. Opex

Subtracting opex from revenue yields a simplified version of net income. Wireless Matrix ranks Italy and U. K. highest in this category; Canada and France lowest; and Japan, Germany, and the U. S. in the middle.

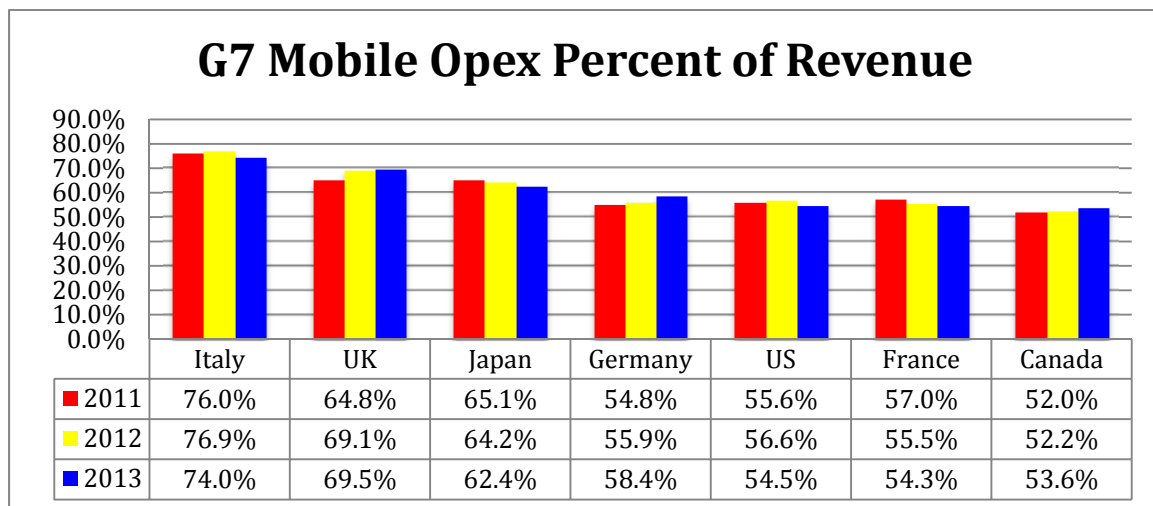


Figure 89: G7 Mobile opex as percent of revenue. Source: Mobile Matrix

This factor reflects revenue and operating efficiency; we expect it to be high in nations that are expensive to serve for geographic reasons and also in those who are behind the technology curve. It will also be high in nations with sharp price competition.

The residue of revenue after opex is subtracted is net income; it's not always appropriate to judge national policy on the basis of net income because it is primarily shaped by non-policy factors and doesn't provide insight into service quality.

iii. Capital Expenditures

For three years, U. K. has spent the most on capex relative to income; Canada and Germany have spent the least; and the U. S., France, and Japan are close together in the middle.

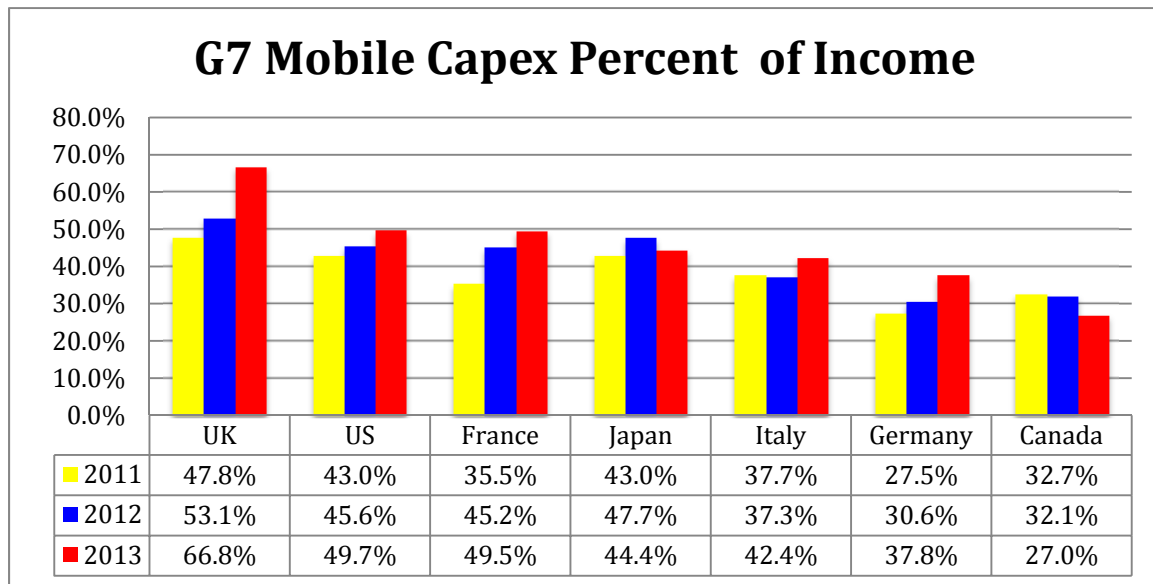


Figure 90: G7 Mobile capex as percent of income. Source: Mobile Matrix¹⁷⁶

Capex is increasing at the highest rate in U. K. and improving in the U. S., Germany, Italy and France as well. It's likely that mobile capex is going into LTE Advanced upgrades and small cells (to increase data rates) in the U. S., and to early-stage LTE coverage improvements in other nations. Historically, the U. S. has been the test bed for network evolution.

iv. Pre-tax Free Cash Flow

Pre-tax free cash flow, the best indicator of carrier profitability, is exceptionally high in Canada and Germany, which indicates mature networks and limited competition. It's lowest in U. K., France, and the U. S., where technology is newer and markets are more competitive. Pre-tax free cash flow is a key term in the Broadband Value Index.

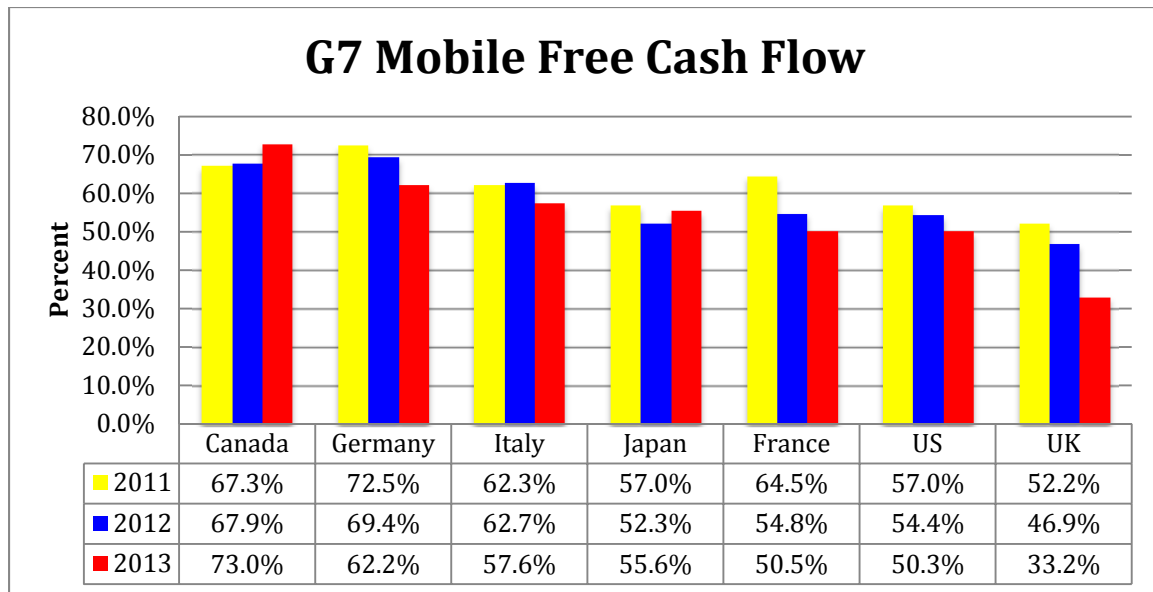


Figure 91: G7 Mobile pre-tax free cash flow as percent of income. Source: Mobile Matrix

v. Mobile Network Consumer Value

As is the case for wired networks, it's reasonable to assess the consumer value of mobile in terms of bandwidth price as a function of provider profit. This method recommends itself because it's an improvement over the "dollars per megabit per second" that hides cost and usage. It's clearly more expensive to operate a geographically dispersed, heavily used network than a compact and lightly used one.

The BAML database breaks down financials by user and by nation, so we can do a much more precise measurement of mobile broadband than wired broadband. As before, the basic formula is:

$$\text{Value} = \frac{\text{provider profit}}{\text{average download speed} \times \text{average data volume}}$$

Profit is simply revenue minus expenses, calculated as EBITDA.

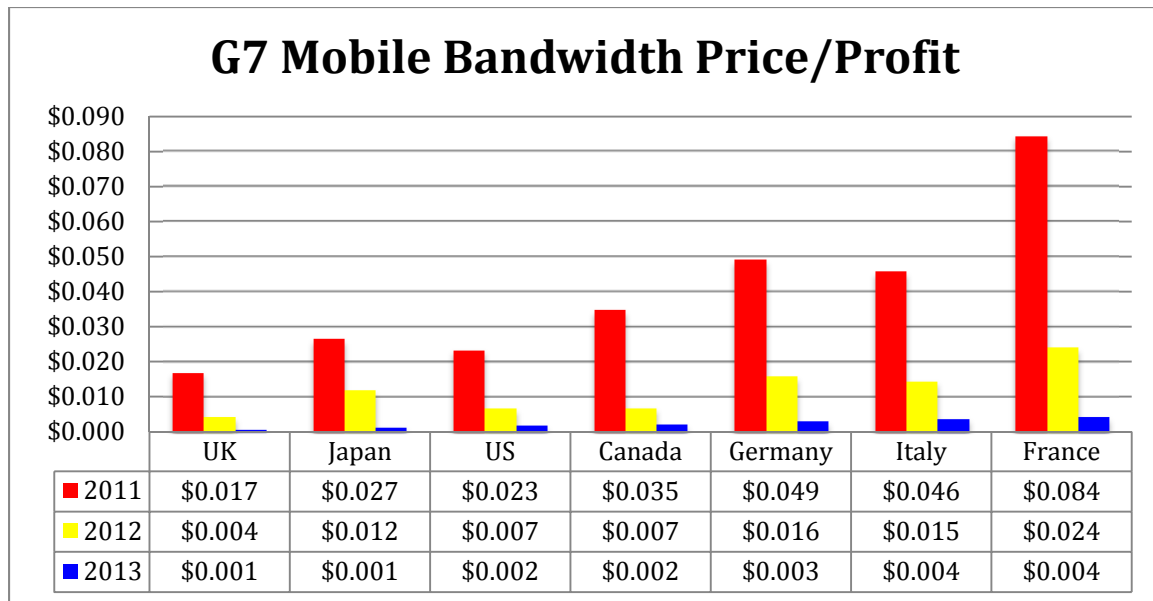


Figure 92: G7 Mobile Broadband Bandwidth Price in Dollars of Provider Profit. Source: author calculations on data from Ookla, Cisco, BAML.

The calculated rates fall very sharply as usage increases. Even in France, the nation with the highest single price in the sample, \$0.84 in 2011, the 2013 bandwidth price in dollars of profit is less than four cents. ARPU held fairly steady in most nations between 2011 and 2013, but usage has skyrocketed.

To see the effect that increased usage has had, it's useful to view the same period in terms of consumer bandwidth prices per provider revenue dollars, ARPU. The revenue chart ranks the U. S. and U. K. differently than does the profit chart.

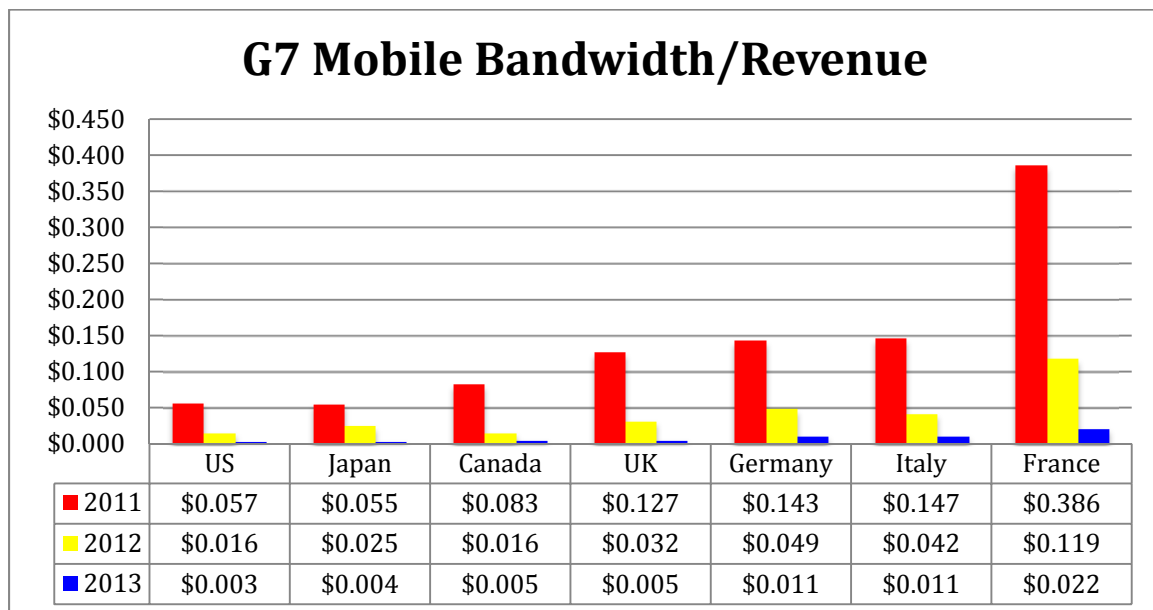


Figure 93: G7 Mobile Broadband Bandwidth Price in Dollars of Provider Revenue. Source: author calculations on data from Ookla, Cisco, BAML and Infonetics.

The distribution of bandwidth prices as functions of revenue and profit cast doubt on claims that mobile networks in the U. S. and Japan are overpriced. While Canada, the U. S. and Japan have the highest 2013 mobile ARPUs in the G7 at \$58, \$52, and \$43 respectively, the usage in these countries is so much higher than it is in other countries that revenue differences wash out when usage is factored into the analysis.

Are complaints about high networking segment prices similarly unjustified by comparison with related sectors? It's worthwhile to examine this question briefly before concluding the G7 analysis.

H. Comparisons of Sector Profitability

While overall focus of this study is on G7 carriers, it's also useful to compare the carrier business segment to the other two elements of the Internet economy, content creators and the intermediaries ("edge services" in FCC parlance) who are the major players in Internet access to content and services. The Internet economy obviously depends on the creation of content and services, their sale to the public, and the transmission of content and services from producers to consumer and from user to user. For the Internet economy to thrive as a whole, it's necessary that there be at least a vague semblance of equity between investment and the extraction of value from the marketplace. Content creators require intermediaries, intermediaries require networks, and networks require content and services, after all.

This analysis focuses on U. S. firms for two reasons: the primary content creators and Internet edge players are U. S.-based; and financial reporting for U. S. firms is uniform. Thus, it's possible to make meaningful comparisons within the U. S. Internet markets.

i. Content Creators

Content creators are the large media firms who produce entertainment, news, and other digital content. The top five firms in this segment by revenue are CBS, Disney, Interpublic, Omnicom, Twenty-First Century Fox, and Viacom. Pre-tax free cash flow analysis shows a profitability range for this group from near 30 percent (CBS) to nine percent (Viacom) in 2013.

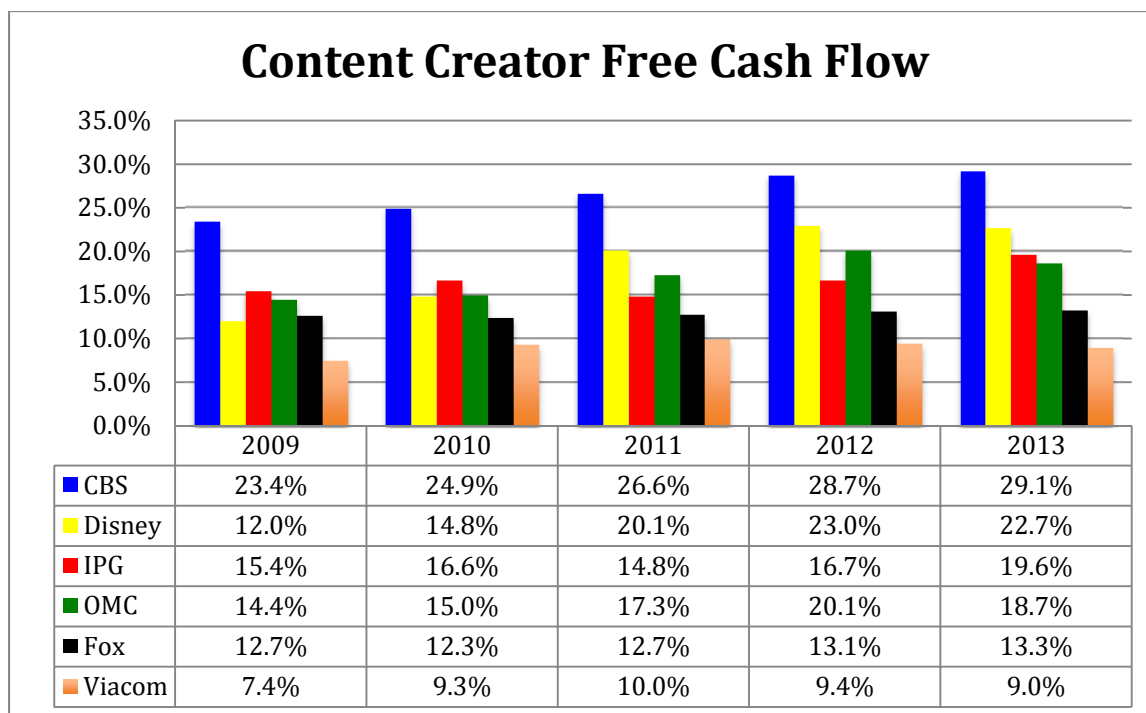


Figure 94: U. S.-based Content Creator Profitability. Source: Fidelity Research

ii. Internet Edge Services

Internet intermediaries are significantly more profitable than the content creators. Priceline's pre-tax free cash flow was more than 60 percent in 2013, and Netflix's was well over 50 percent. Amazon is an exception, as it invests all the money it makes in business expansion; its pre-tax free cash flow has been negative for the past two years.

The three top firms in this segment, Priceline, Netflix, and Facebook, all produce more pre-tax free cash as a percentage of revenue than the top firm in the content segment.

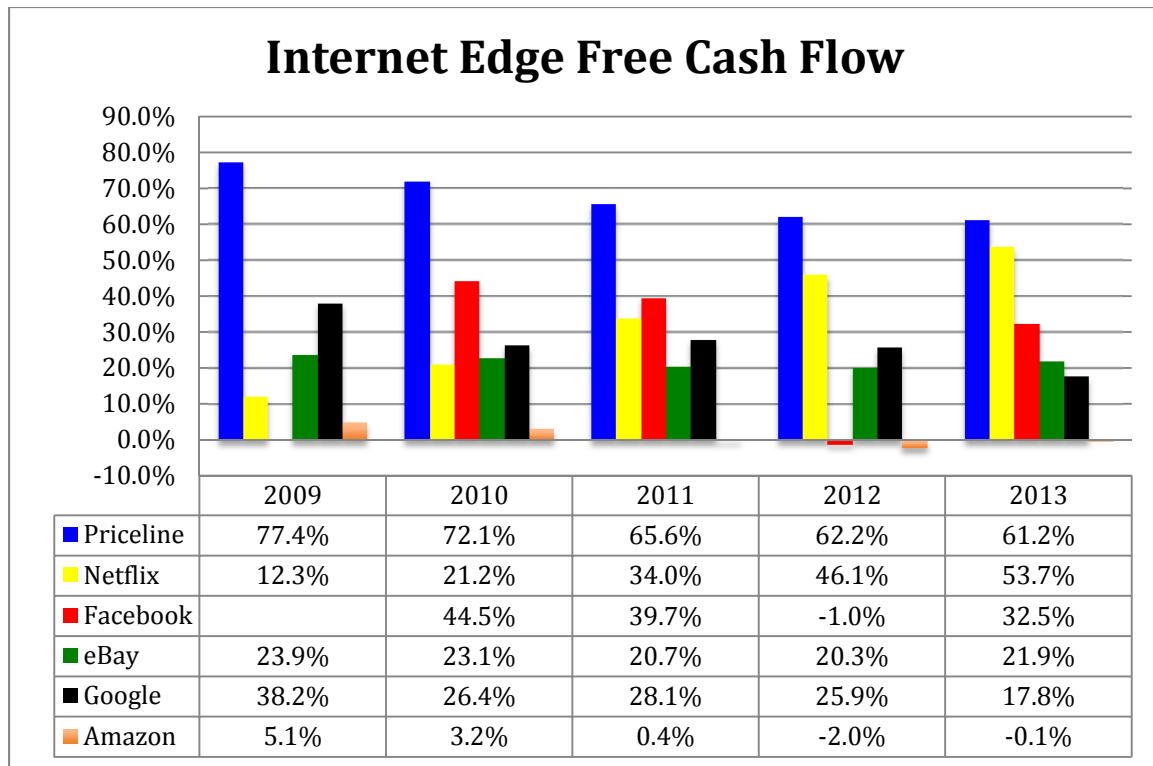


Figure 95: U. S.-based Internet Intermediary Profitability. Source: Fidelity Research

iii. Network Service Providers

The leading pre-tax free cash producer in the network services sector is Verizon, earning enough to place second among content creators and fourth among intermediaries. Profitability is more uniform in this segment than in the others, although T-Mobile U. S. is significantly behind the leaders.

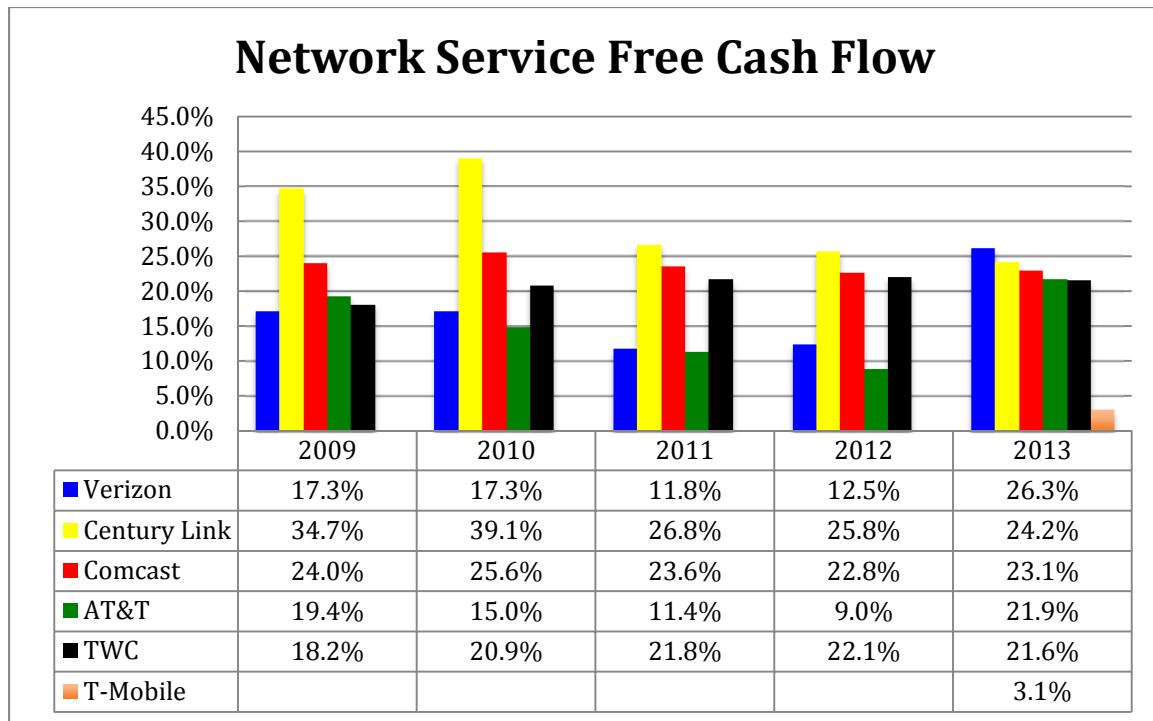


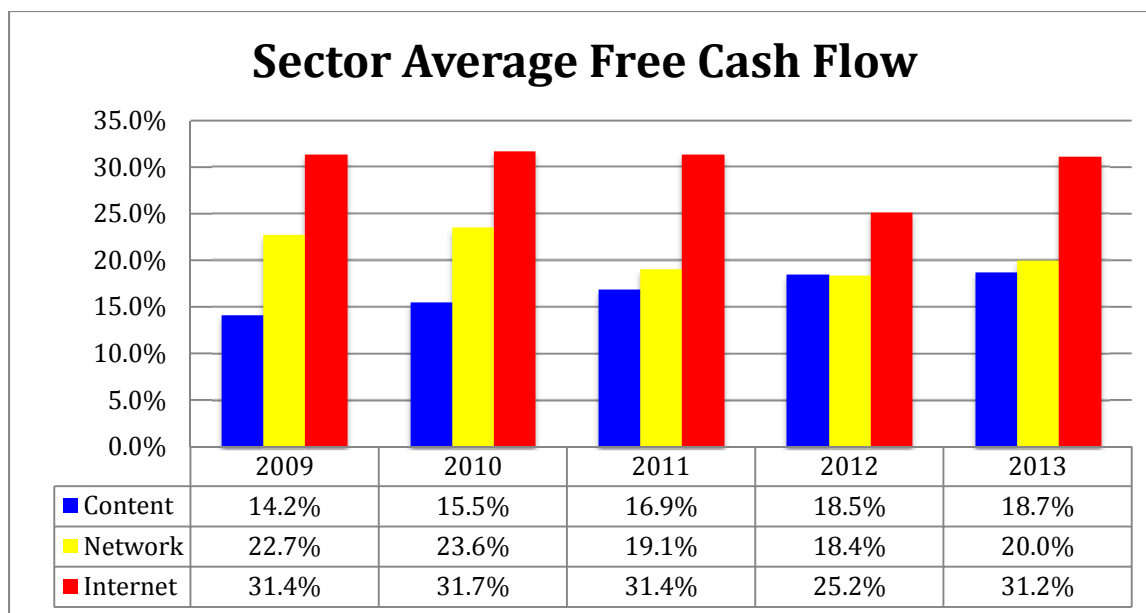
Figure 96: U. S.-based Carrier Profitability. Source: Fidelity Research

iv. Summary

A simple average of pre-tax free cash flows for the leading firms in the three sectors shows a fairly consistent distribution of profit: the Internet edge intermediaries are the most profitable firms, and in most years the content creators are the least profitable. In 2013, Internet firms were 56 percent more profitable than network service providers, and 67 percent more profitable than content creators.

Uneven distribution of profits drove the “Stop Online Piracy Act” (SOPA) and the “Protect IP Act” (PIPA). Internet firms in the advertising sector profit from piracy while content creators, networks, and legitimate content resellers such as Netflix suffer from it.

Would greater profitability by content creators and networks produce more content and better networks? This depends on the willingness of firms to invest profits in business expansion and improvement, but the answer is probably “yes”.



I. Comparisons of Sector Total Return

Total Return is interesting to investors, because it measures their rewards for investing in a company's stock. Total return measures dividends and share price increases over time. It's not a measure of the firms' profitability in its own right as much as of the market's perception of that value. But the market is quite astute; one year total return ranks firms in the same order that pre-tax free cash flow does.

i. Content Creator

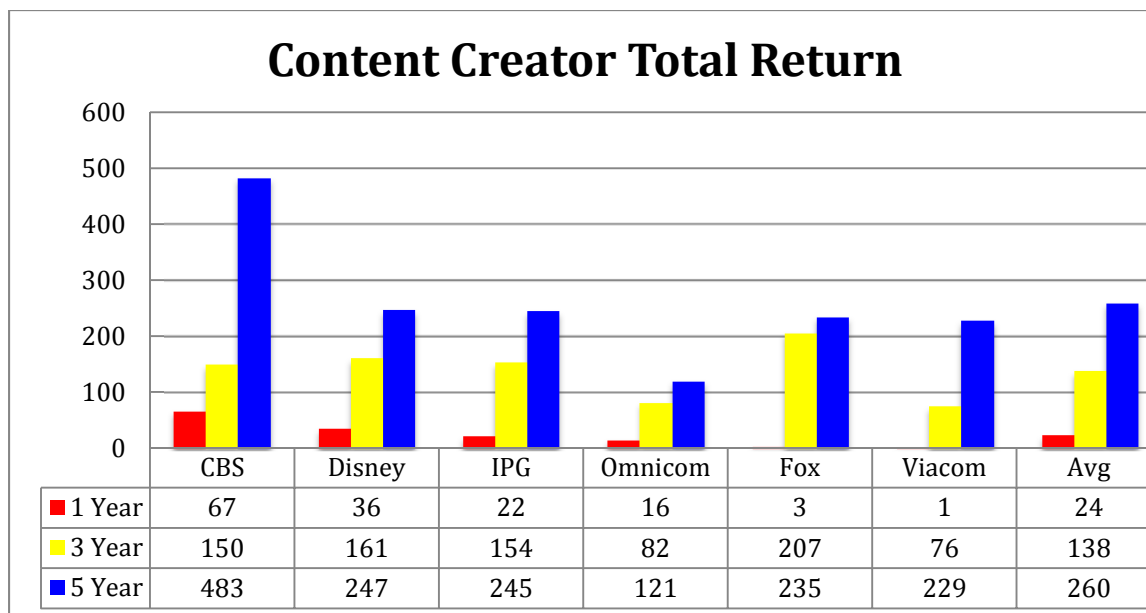


Figure 97: U. S.-Based Content Creator Total Percent Return. Source: Fidelity Research

ii. Internet Edge Services

Internet edge services have historically earned high returns for shareholders, and they still produce greater rewards than the media and networking segments do even though the gap has shrunk considerably. On a five-year basis, Internet firms have produced a 441 percent return, nearly double that of the content segment and more than double the network return. Amazon, eBay, and Google lost a great deal of favor with investors in 2013; Google has regained a small portion of its luster, but the others continue to decline.

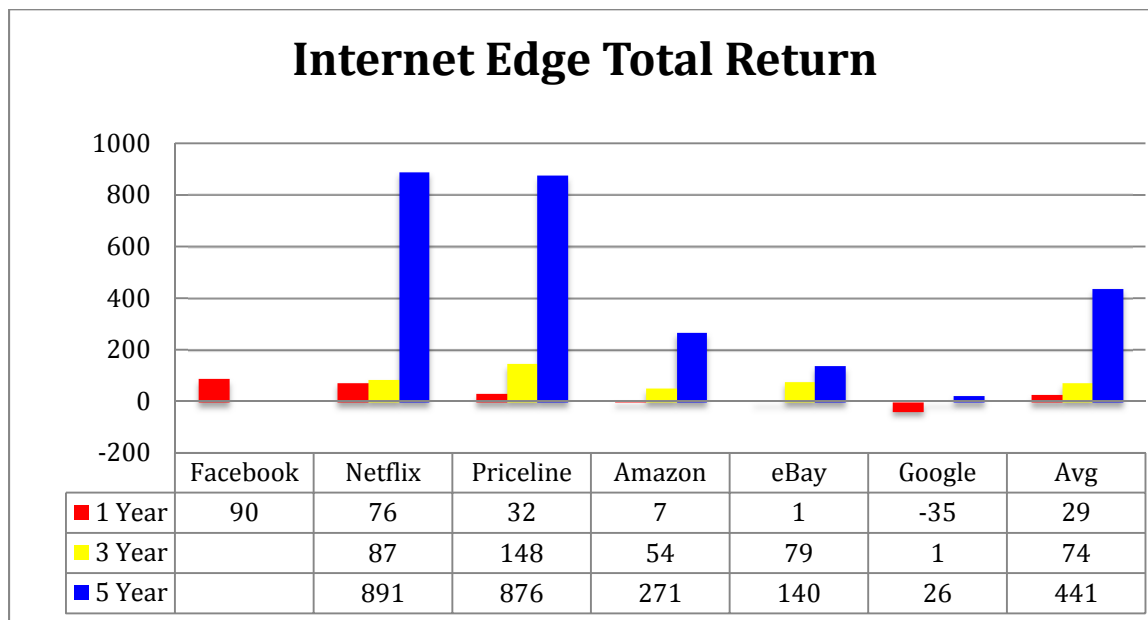


Figure 98: U. S.-Based Internet Intermediary Total Percent Return. Source: Fidelity Research

Market valuation in this sector generally tracks financial performance, with the exception of Priceline, which the market undervalues, and Facebook, which it overvalues on a twelve-month basis. But Priceline's profits have declined for five years, while Facebook appears to have a bright future.

iii. Network Service Providers

The stock market is less efficient at valuing networking companies than other firms, as there is very little correlation between total return and profitability in this sector. Verizon ranks at the top of my (very approximate) pre-tax free cash flow calculation, but next to last in total return. This may indicate either an error in my analysis, or an analyst bias against Verizon stemming from its decision to invest \$23B in its FTTH network.

Time Warner Cable and T-Mobile produced outsized returns in 2013 because of speculation, as investors placed their bets on mergers and growth prospects. The market is not impressed by the "mobile duopoly" of AT&T and Verizon; it appears their shares are currently undervalued.

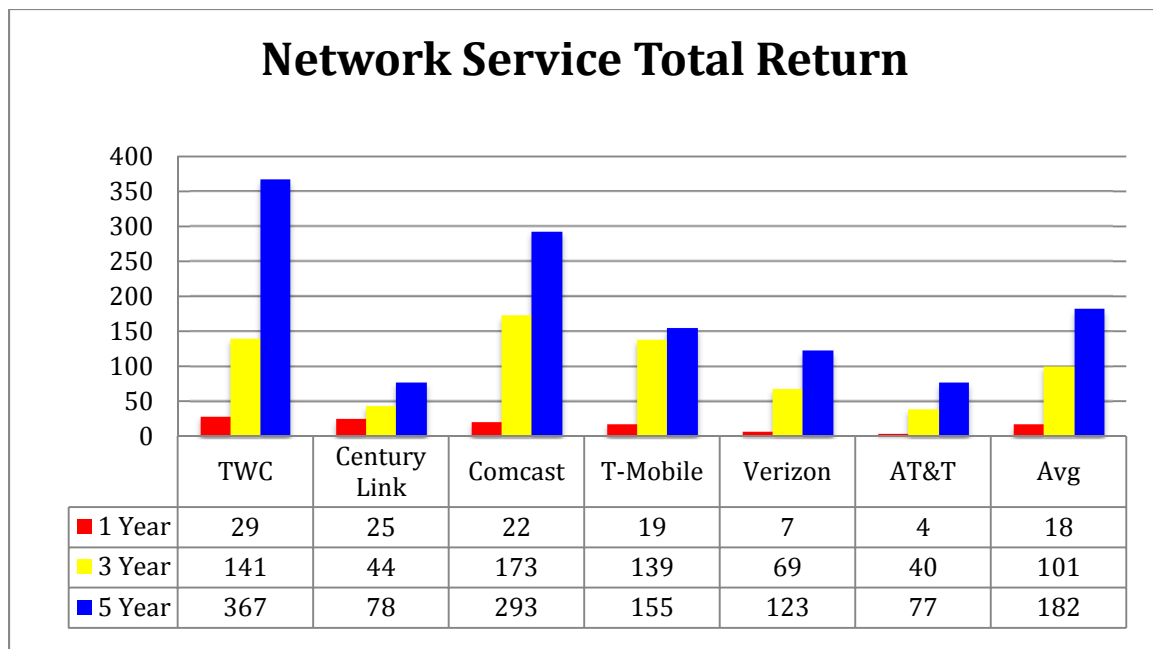
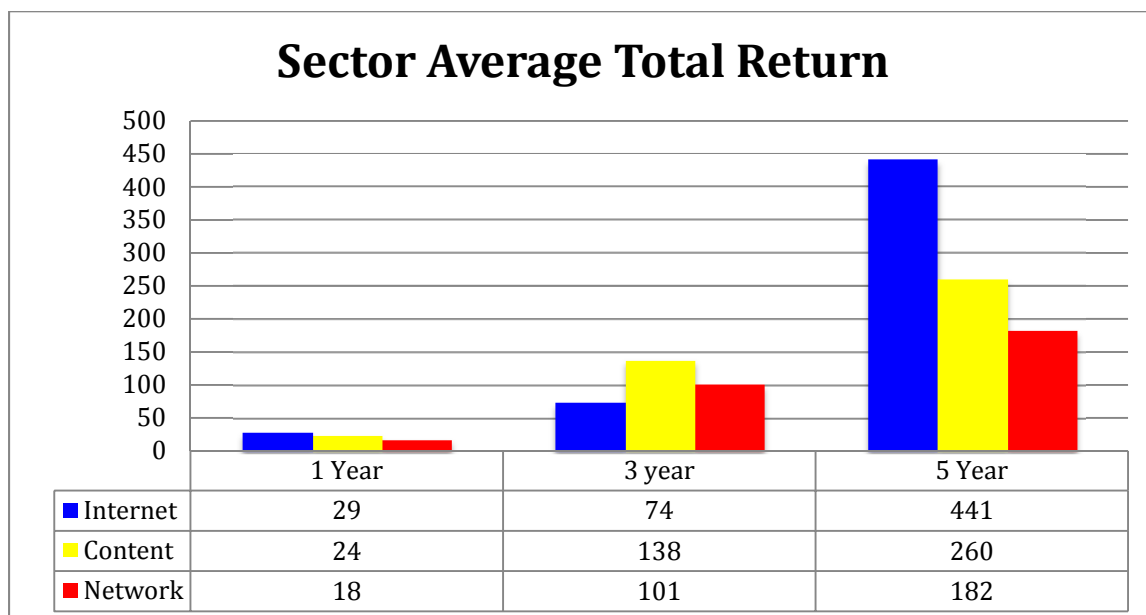


Figure 99: U. S.-Based Broadband Carrier Total Percent Return. Source: Fidelity Research.

iv. Summary

It's better to own shares in an Internet company than in a content or networking firm at the moment. The collapse of a bubble depressed returns for Internet companies over the three-year horizon, where they ranked behind the other two segments. But Internet firms returned to first place in 2013, consistent with the five-year horizon in which they hold a massive lead over the other segments.



J. Comparisons of Sector Return on Invested Capital

Return in Invested Capital (ROIC) is the best way to evaluate the profitability and leverage of capital-intensive businesses. The Morningstar *Investor's Classroom* explains its significance:

The best way to determine whether or not a company has a moat is to measure its return on invested capital (ROIC). This is similar to ROA but is a bit more involved. The upshot is it gives the clearest picture of exactly how efficiently a company is using its capital, and whether or not its competitive positioning allows it to generate solid returns from that capital.¹⁷⁷

According to Morningstar, firms with 15 percent or more ROIC for a number of years most likely have a “moat” that protects them from competition.

i. Content Creator

Among content creators, only Viacom produces ROIC greater than 15 percent, just breaking that threshold in the last two years.¹⁷⁸

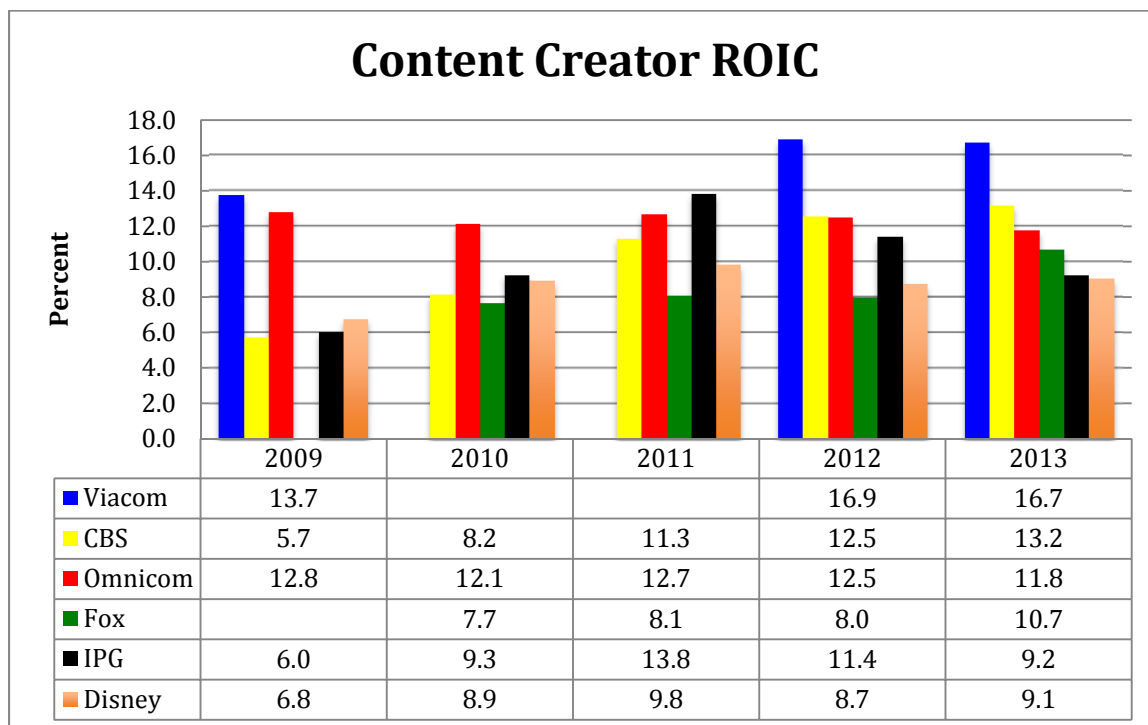


Figure 100: U. S.-based Content Creator Return on Invested Capital. Source: Bloomberg

Viacom's Paramount Pictures unit produces unusually large profits from an unconventional approach: it produces fewer movies than its rivals, but more profitable ones:

Paramount ranks last among major studios (and even behind the mini-major Lionsgate) in the annual box-office race, with under \$900 million to date in domestic ticket sales, down by half from its recent peak in 2011. Yet Paramount has become consistently profitable in an industry where profit margins have ranged from razor-thin to nonexistent.¹⁷⁹

None of the other content creators produce such high returns on invested capital.

ii. Internet Edge Services

Among Internet edge providers, Priceline is effectively insulated from competition for the time being, but its position has eroded steadily since 2010, as has Google's.

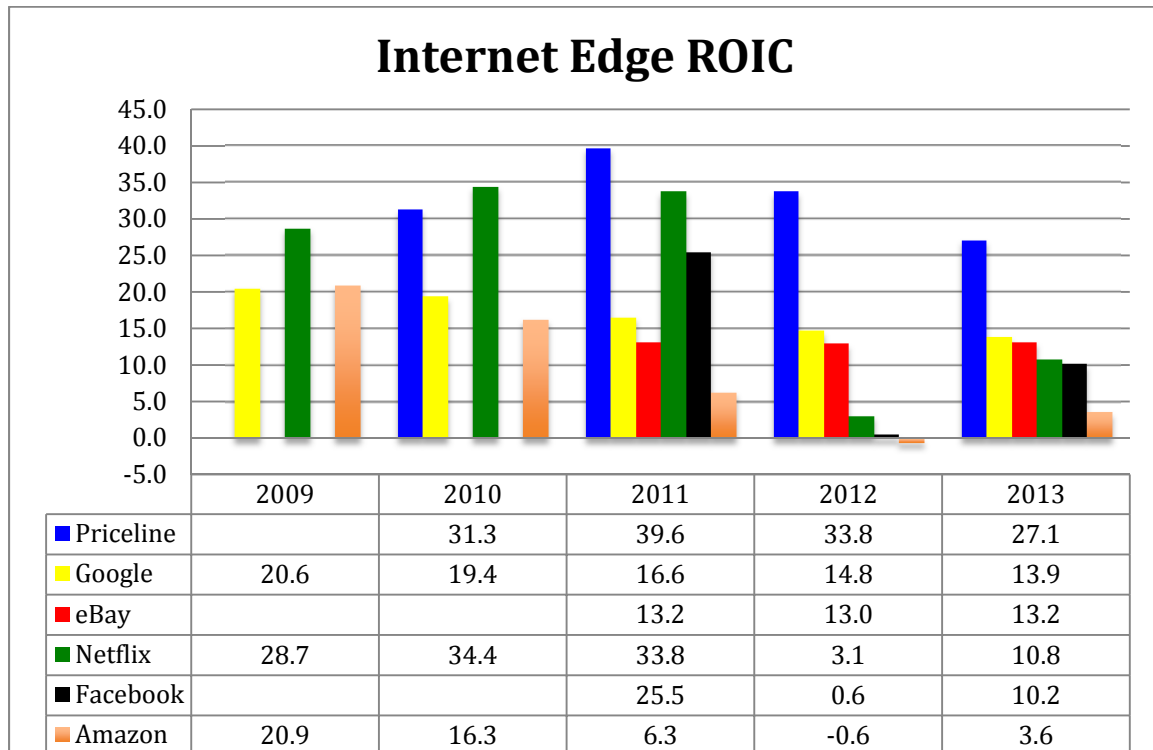


Figure 101: U. S.-based Internet Edge Services Return on Invested Capital. Source: Bloomberg.

Netflix's ROIC has declined sharply since it has begun to invest in content and in a Content Delivery Network, but the major part of its long-term ROIC outlook comes from its pivot from DVD rentals to streaming. Despite consumer preference for streaming, which has accounted for most Netflix revenue since 2013, DVD rental is a more profitable business; Netflix margins on DVD rental are 50 percent, but only 25 percent on streaming. Streaming produces more total profit because more people do it.¹⁸⁰

iii. Network Service Providers

The network services sector doesn't contain a "moated" player, and it's fair to say that networking firms are jealous of the returns earned by content and edge services firms. Verizon leads the sector with 2013 ROIC of 13.1 percent, not far below Google's 2013 value. This data point is an anomaly for both Verizon and the sector as a whole, however, as the average ROIC for the sector is a quite modest 6.4 percent.

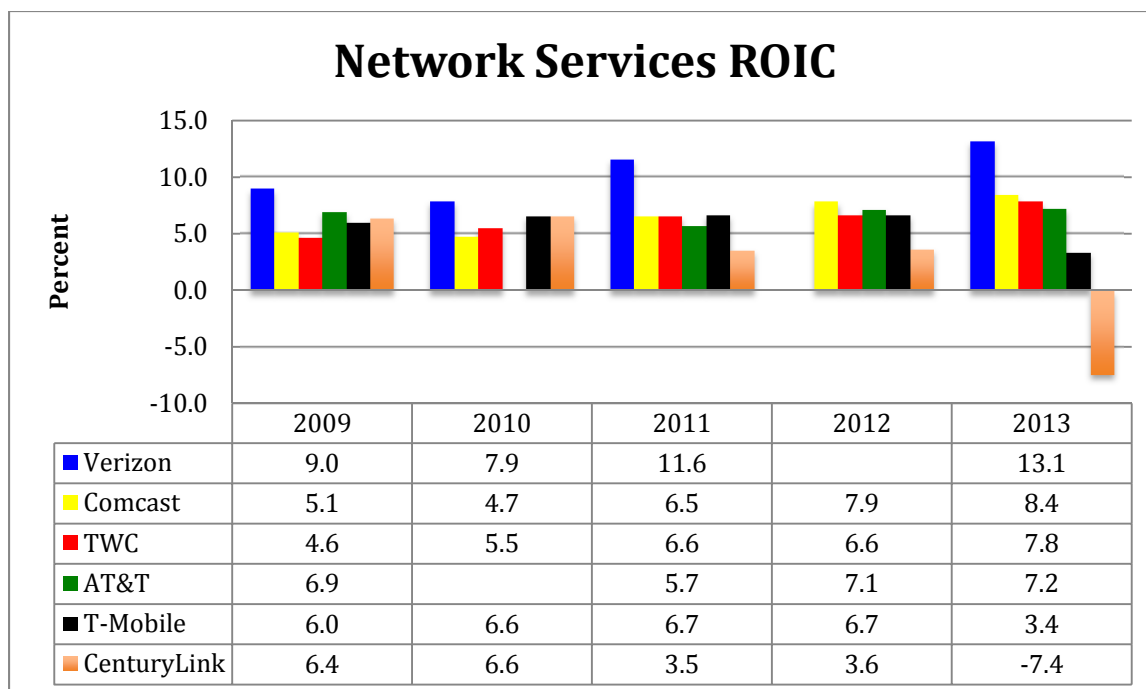


Figure 102: U. S.-based Network Services Return on Invested Capital. Source: Bloomberg

CenturyLink's negative ROIC is the largest negative value in the entire survey, beating Amazon's -0.6 2012 value by an order of magnitude. Clearly, networking firms invest more heavily and achieve lower returns than firms in the content and edge services segments.

iv. Summary

Averaging ROIC across all firms in each sector and then comparing sector averages confirms the impression that the Internet sector is most profitable and best protected from competition. Using Morningstar's criterion of ROIC in excess of 15 percent for several years constituting a "moat", Internet Edge Providers are protected from competition; they've averaged 17.8 percent ROIC over the past five years.

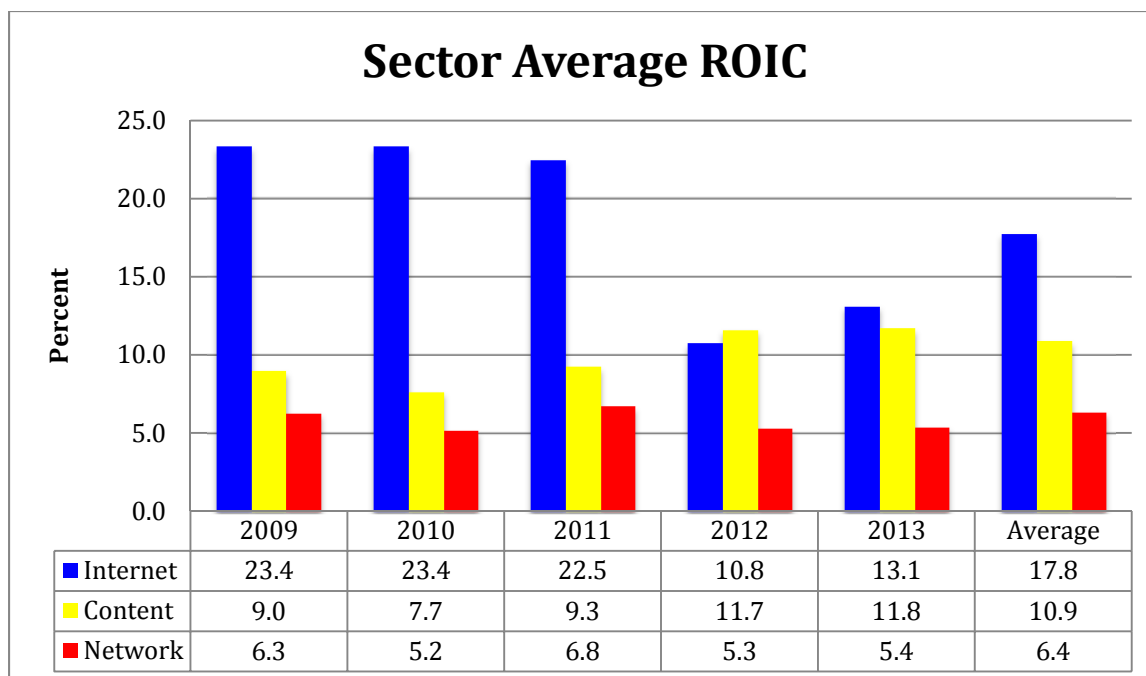


Figure 103: Sector Average ROIC. Source: Bloomberg

Thus, Internet firms have produced 63 percent greater return on invested capital than Content Creators and 178 percent greater return than Network Service providers. There's clearly no factual basis on which to charge networking companies with being excessively profitable.

K. Total Telecom Investment

Returning to the G7 context, the final measurement to examine is investment per capita; our previous treatment of investment (capex) compared it to net income. The International Telecommunications Union, a specialized U. N. agency for information and telecommunications technology, publishes a comprehensive annual database of broadband indicators including an investment survey.¹⁸¹ According to ITU, U. S. telecom firms invest \$19.42 per person per month.

The ITU database confirms findings by Mercatus and CTIC to the effect that U. S. firms invest more heavily than European ones, and extends the finding across the globe.¹⁸² The U. S. is not the heaviest investor in the G7 however; Canada invests even more, but the difference is not large. Within the G7, both France and Italy have stepped up their game, increasing investment in the mobile sector.

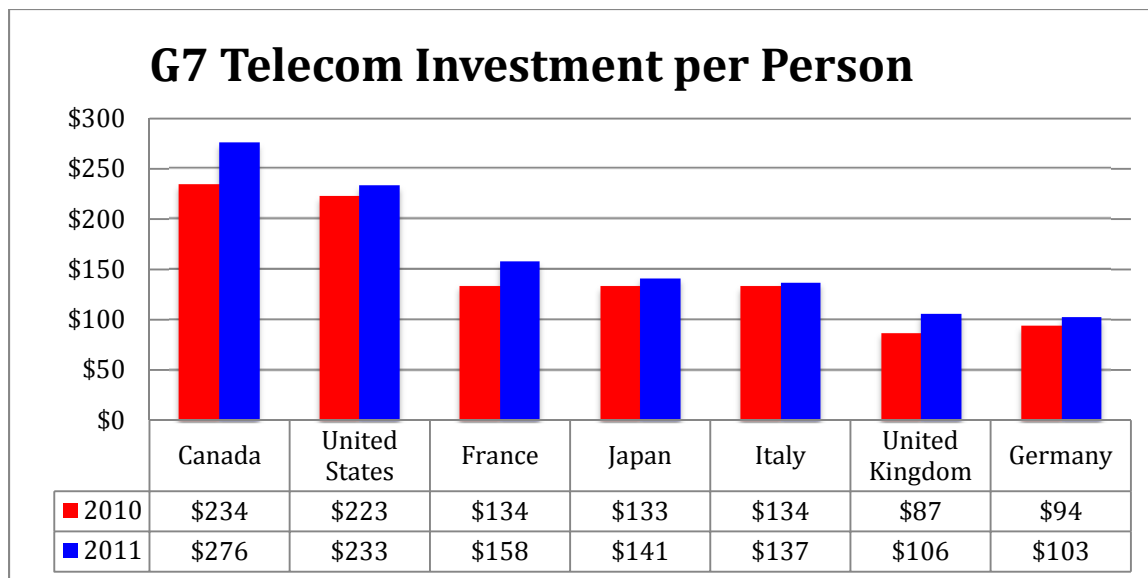


Figure 104: G7 Telecom Investment per capita. Source: ITU¹⁸³

The rank ordering the ITU investment survey is same on a per capita basis as on a per household basis. On this basis, \$51.25 of the monthly communication bills paid by each household go straight to investment.

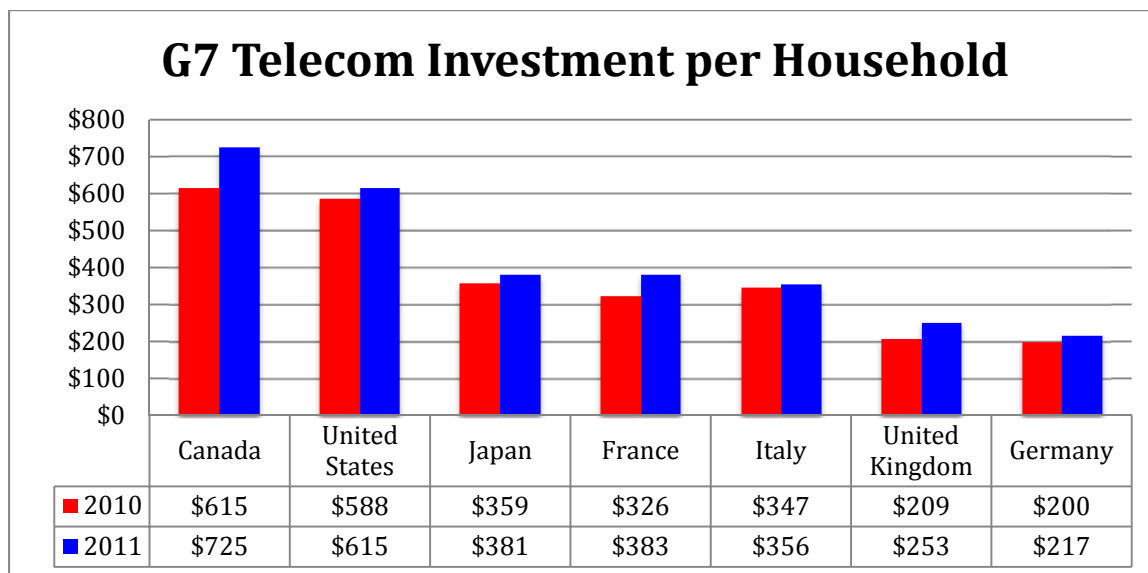


Figure 105: G7 Telecom Investment per household. Source: ITU

The high level of investment by U. S. and Canadian firms explains why these countries are usually first to deploy new broadband technology.

7. Policy Analysis

Now that we've surveyed the data on deployment, adoption, performance, cost, price, and value, we're in a position to assess the policies that have helped produce the results we've seen. The policy choices of interest follow from the following goals:

1. Universally Available Service
2. Universal Adoption
3. Continual Technology Displacement
4. Low Consumer Price
5. Increasing Consumer Value

These five pillars of broadband policy are often in tension with each other. Technology displacement, for example requires capital investment. Investment comes at the expense of consumer prices, even though it may increase consumer value in the long term; e.g., enabling consumers to reap positive externalities that come from making tomorrow's networks better than today's.

Universal service is at the same time a prerequisite to universal adoption and a barrier; to the extent that consumers in first-served locales are attracted by low prices, carrier profits may be trimmed to the point that service extension into higher cost locales is unattractive. Subsidizing rural service can resolve this dilemma, but doing so raises the social cost of broadband, albeit in a way that may go unnoticed by voters and even by regulators.

A. Initial U. S. Policy

The history of U. S. broadband policy tends to be poorly understood because two issues are intertwined, intermediary liability and access to infrastructure. Common carrier systems such as the traditional telephone network protect service providers from liability for the actions of their users: if you and I conspire to commit a crime in a series of telephone calls, the telephone company cannot be held responsible for our actions. Third party liability for the (often criminal) actions taking place over the broadband network wasn't firmly decided until the court ruled, in 1997, that Section 230 of the Digital Millennium Copyright Act protected online services from the consequences of their users' actions.¹⁸⁴ Prior to this seminal moment, some broadband carriers were drawn to common carrier treatment for liability reasons.¹⁸⁵

When the FCC initially classified DSL as a Title II common carrier service in its 1998 "Advanced Services Order", carriers Bell Atlantic and SBC asked the Commission to use the authority granted by Section 706 (a) of the 1996 Telecommunications Act to forbear from imposing Title II open access and price control regulations from DSL.¹⁸⁶ The FCC argued that it lacked this authority, and the court affirmed the FCC's reading of the law.¹⁸⁷ The FCC and some advocates now claim, interestingly, that Section 706 (a) does grant broad authority to forbear from any and all provisions of Title II as it wishes.

Broadband provided over cable has never been classified a common carrier service by the FCC, although it did hold that status within the Ninth Circuit's jurisdiction from 1999 until the FCC formally classified it under Title I in 2002.¹⁸⁸

B. The Great Pivot

After the FCC's Declaratory Ruling classifying Internet access over cable modem as an "Information Service" was upheld by the Supreme Court in the Brand X case in 2005, the FCC reclassified DSL as an Information Service as well.¹⁸⁹ This put an end to mandatory LLU ("open access") in the United States.

These actions were widely anticipated, hence the notion of "net neutrality" as a potentially superior regulatory policy was already under development; Tim Wu's first

memo on net neutrality was written in 2002, and his first journal article was written shortly thereafter.¹⁹⁰ Wu's article, *Network Neutrality, Broadband Discrimination*, argues that net neutrality is a stronger tool than unbundling for preventing anti-competitive vertical integration while permitting beneficial integration:

True application neutrality may, in fact, sometimes require a close vertical relationship between a broadband operator and Internet service provider. The reason is that the operator is ultimately the gatekeeper of quality of service for a given user, because only the broadband operator is in a position to offer service guarantees that extend to the end-user's computer (or network). Delivering the full possible range of applications either requires an impracticable upgrade of the entire network, or some tolerance of close vertical relationships.

This point indicts a strict open-access requirement. To the extent open access regulation prevents broadband operators from architectural cooperation with ISPs for the purpose of providing QoS dependent applications, it could hurt the cause of network neutrality. By threatening the vertical relationship required for certain application types, it could maintain IP's discrimination in favor of data applications. More broadly, this argument shows that the concept of network neutrality cannot be taken as counsel against all vertical integration.¹⁹¹

The FCC's classification of cable modem as an Information Service and its corresponding reclassification of DSL was intended to stimulate the broader deployment of advanced broadband networks across the U. S. The U. S. had this policy option - relying on competition rather than regulation to achieve national goals - because we had competing broadband facilities and a legal framework that directed the FCC to stimulate the deployment of "advanced networks" in Section 706 (a) of the 1996 Act.

U. S. broadband policy has largely remained as it was in 2005: the market is generally deregulated apart from on-again, off-again net neutrality strictures, and unhappy advocates for greater regulation continue to make a case for greater government intervention, often on a flawed factual foundation.¹⁹²

C. Other G7 Case Histories

Apart from Canada, facilities-based competition was not an appealing option in the G7 until nations confronted the issue of technology upgrades that required new or reconfigured wiring. Europe and Japan still employ official policies that mandate a right of wholesale access to the DSL incumbent's lines in the interest of promoting low prices and competition between ISPs, but the details of wholesale access terms can have the effect of nullifying the policy.

If the access price is too high to be attractive to would-be retail ISPs, the open access regime effectively becomes a facilities-based model. If they're too low, the system stagnates and consumers have little incentive to choose higher performing but more costly upgrades. By its nature, low-priced mandatory wholesale access is a boon to adoption and a barrier to technical progress. The following section is an attempt to tease out the implementation of price controls and subsidies in order to determine where the rest of the G7 stands with respect to this delicate policy balance.

i. Canada

Canada's broadband policy is a close cousin of America's: in urban markets, broadband is largely deregulated, and in rural areas it is heavily subsidized.¹⁹³ For all practical purposes, Canada and the U. S. follow the same regulatory model; it can be termed the "Pioneer Model" as it rewards first movers and risk-takers.



Figure 106: 25 Communities in Nunavut. Source: Hudson.

As the population data shows, Canada's rural population is sparse, with an average rural density of 14 persons per sq. km. of arable land. Canada's north features vast, sparsely populated areas beyond the tree line.

For reasons that become obvious upon inspection, satellite and terrestrial wireless networks serve these regions, not wireline.

The map shows the locations of 25 communities in Nunavut that house 30,000 people and span two million sq. km. Canada's rural population spread is similar to Alaska's, a state in which half the people live in one city.

There is a degree of competition even in these remote areas, however. While one firm, SSI Micro, maintains backhaul facilities, local Internet services are

provided by Community Service Providers (CSPs).

Canada's national broadband plan, *Connecting Rural Canadians*, was enacted in 2010. It emphasizes subsidy programs, matching grants, and federal/provincial partnerships. Canada continues to raise speed targets; in 2011, CRTC established a goal of 5 Mbps for all Canadians by 2015.¹⁹⁴ Without increased spending in remote areas this target will not be achieved.

In 2014, Canada's Ministry of Industry published a plan to stimulate the larger digital economy, Digital Canada 150.¹⁹⁵ This plan adds \$305M to the rural subsidy budget toward the 5 Mbps goal, but scales the goal back to 98 percent of Canadians.

Digital Canada 150 is a broad program that deals with subjects ranging from channel unbundling to cyber-bullying, but the emphasis on the infrastructure portion (apart from rural subsidies) is primarily on mobile, particularly on the desire to lower mobile service bills.

Canada clearly considers urban broadband infrastructure a solved problem and seeks to stimulate more effective utilization.

ii. Japan

Professor Toshiya Jitsuzumi of Kyushu University in Fukuoka, Japan contributes the following account of Japan's broadband policy history.

Japan's Broadband Strategies

Broadband service in Japan was first provided by a cable firm (Musashino-Mitaka Cable Television) in Tokyo in October 1996, and ADSL first became available in Nagano prefecture in August 1999. However, at the turn of the century, Japan's Internet penetration was the lowest among developed nations as most accessed the Internet via POTS or ISDN; broadband users were less than 5 percent. In order to improve this situation - and make Japan the most advanced IT nation in the world - the Japanese government passed the IT Basic Law in November 2000, created the IT Strategy Headquarters in January 2001, and mapped out a strategy called the "e-Japan Strategy."

The e-Japan Strategy found that significant reasons behind the unacceptable status quo included high access fees and usage limitations, both of which were considered to be the result of the overwhelming dominance of the local communications market by NTT-East/West (NTT-E/W). It targeted the development of the world's top network, with broadband available to more than 30 million households and ultra-broadband (over 30 Mbps) available to more than 10 million households within 5 years. Then, it called for creating fair competition in the telecom sector and facilitating fiber deployment.

To this end, the Ministry of Public Management, Home Affairs, Post, and Telecommunications (MPHPT), which was then renamed to the Ministry of Internal Affairs and Communications (MIC), utilized the already-introduced asymmetric regulation, interconnection rules, and other related policies in the Telecommunications Business Act. These initiatives finally enabled Japan to achieve its target in only three, not five, years. The asymmetric regulation requires the owner of a dominant local network (in this case, NTT-E/W) to make its network widely available to competitors on favorable conditions and does not allow it to prioritize any partner companies; it is widely believed that this asymmetric regulation, accompanied with NTT's own initiative for open networks made public in February 1995, paved the way for the success of competitive broadband firms, especially ADSL providers, and greatly helped Japan to achieve its goal.

Since then, the primary focus of Japanese ICT strategies (e-Japan II in 2003, IT New Reform Strategy in 2006, i-Japan Strategy 2015 in 2009, New Strategy in Information and Communications Technology in 2010, and Declaration to be the World's Most Advanced IT Nation in 2013) shifted from expanding broadband coverage to promoting its usage. Expanding broadband coverage to the nationwide market was mostly done by private initiatives, firstly of ADSL operators and then of FTTH providers.

Year	ICT Initiatives of the Japanese Government
2000	IT Basic Law
2001	IT Strategy Headquarters
2001	e-Japan Strategy
2003	e-Japan Strategy II
2006	New IT Reform Strategy
2009	i-Japan Strategy 2015
2010	New Strategy in Information and Communications Technology
2013	Declaration to be the World's Most Advanced IT Nation

Figure 107: ICT Initiatives of the Japanese Government.

The MIC helped their businesses through interconnection rules, reducing access fees to existing network infrastructure, settling disputes among operators, and issuing direct orders if needed.

It is important to note that, since the terms of local loop unbundling of fibers could not fully satisfy the needs of competing providers¹⁹⁶, competition in the FTTH deployment is far less than ADSL's. According to the MIC¹⁹⁷, as of September 2007, 79.3 percent of local fibers were installed by NTT-E/W and 70.7 percent of the retail market has been controlled by them. On the other hand, NTT-E/W installed 99.96 percent of copper lines, which can be converted into ADSL, but controlled only 37.4 percent of the retail market. NTT-E/W's joint market share in the growing retail FTTH market reached 72.5 percent as of March 2013¹⁹⁸.

Broadband Availability among Japanese Households		
	<i>Ultra-broadband</i>	<i>Broadband</i>
<i>June, 2006</i>	<i>81.0 percent</i>	<i>95.0 percent</i>
<i>March, 2007</i>	<i>83.5 percent</i>	<i>n.a. (95.2 percent)</i>
<i>March, 2008</i>	<i>86.5 percent</i>	<i>n.a. (98.3 percent)</i>
<i>March, 2009</i>	<i>90.1 percent</i>	<i>99.7 percent (98.8 percent)</i>
<i>March, 2010</i>	<i>91.6 percent</i>	<i>99.9 percent (99.1 percent)</i>
<i>March, 2011</i>	<i>92.7 percent</i>	<i>100 percent (99.2 percent)</i>
<i>March, 2012</i>	<i>97.3 percent (96.5 percent)</i>	<i>100 percent (99.7 percent)</i>
<i>March, 2013</i>	<i>99.4 percent (97.5 percent)</i>	<i>100 percent (99.8 percent)</i>

Figure 108: Broadband Availability among Japanese Households. Source: MIC

Note: Numbers in parentheses are household coverage by fixed broadband.

However, as it was considered insufficient to rely solely on private incentives to realize ubiquitous broadband availability, the MIC formulated the Strategy on Bridging the Digital Divide in 2008, financially supporting municipal FTTH projects. In 2010 the MIC set a new target -- realizing ultra-broadband availability, or coverage, at all households by around 2015. Thanks to these efforts and competition among private providers, as of the end of March 2013, ultra-broadband, or FTTH, was available to 99.4 percent of all Japanese households (53.81 million households) and broadband to 100 percent - Toshiya Jitsuzumi.¹⁹⁹

In summary, Japan used the open access regime for leverage to achieve the goal of universal ultra-broadband ahead of market demand. It achieved this result by setting wholesale access rates too low for NTT-E/W to achieve profitability from the copper network alone. Simultaneously, it allowed NTT-E/W greater flexibility with the terms

and conditions of FTTH line sharing, making it clear that NTT-E/W needed to invest in FTTH if the newly privatized firm was to become profitable. The contrast is clear in the market shares for DSL and FTTH: NTT-E/W has 37.4 percent of the market for retail DSL and 70.7 percent of the retail market for FTTH. Competitors can buy dark fiber from NTT-E/W, but only in groups of eight strands at a time. This form of conditioning access to volume is known as the “contingent model” in Europe, where it is the norm for advanced network access in Germany and, to a certain extent, in U. K.²⁰⁰

Below-wholesale prices for DSL depress the market rate for FTTH, however, and Japan’s wired broadband industry generates negative cash flow (see: Figure 83). This has forced NTT to turn to its mobile operation, DoCoMo, for profit. NTT DoCoMo is Japan’s largest mobile operator.

German and U. K. regulators are using a version of Japan’s contingent strategy to encourage broadband infrastructure firms to install Next Generation Access networks today, in order to catch up with the U. S., Canada, and Japan.

iii. European Commission Directives

Members of the European Union (EU) are hypothetically bound by common European Commission (EC) telecom regulations such as the *2000 Local Loop Unbundling Directive* and the *2002 Framework, Access and Interconnection, Universal Service, Competition*, and other directives.²⁰¹ EC telecom directives are not self-executing, however; each state must “transpose” the directive into national law, and each state’s NRA must then enforce it. This process always involves the injection of national policies:

*Instead of the somehow deterministic vision of a uniform European information society, the national and local distinctiveness of the EU member states arises as an intervening factor that paints a diverse and differentiating picture of the information society across the EU: “there are many different configurations of the European Information Society. These configurations involve different industrial structures, different roles of users, and different approaches to policy in both the private and public sectors”.*²⁰²

As one might reasonably expect, the unbundling mandate produces a small but still substantial degree of competition, low prices, and a fairly rapid buildout in urban areas, but it has low impact in rural ones. The unbundling mandate also discourages investment in advanced networks; several means such as “investment ladders”, “stepping-stones”, subsidies, and regulatory holidays are used in an attempt to escape from that effect, with varying degrees of effectiveness.²⁰³

The EC does more than simply issue edicts, however; it also acts as a convener for public/private partnerships and hectors member states to support projects of mutual interest such as its 5G Public-Private Partnership launched in December with an indicative budget of €700M.²⁰⁴

The EC approach to network regulation presupposes visions about technology development and even a theory of history. According to the EC vision, technology markets unfold because regulators make them develop; according to a contrary view, “accidents of history” and ingenuity play a larger role. If the latter is the case, information gathering is a more important function for policy makers than regulation. Many nations, including some EU founders, firmly believe the “accidents of history” view is more accurate and beneficial.

iv. United Kingdom

U. K. was the source of the EC unbundling and competition directives as a consequence of being the first to privatize its telephone network. It has modified the basic European approach by adopting “contingent model” measures similar to those used by Japan and Germany.

The basic European approach is a fine prescription for the first stage of Basic Broadband, but it fails in the second stage because the local loop must be reconfigured for Advanced Broadband; this requires both investment and coordination. As Plum Consulting explains, U. K. regulator Ofcom has changed course with respect to its Local Loop Unbundling (LLU) policy, shifting from an emphasis on bitstream competition (Wholesale Line Rate, WLR) to direct-to-wire (Metallic Path Facilities, MPF, and Shared Metallic Path Facilities, SMPF) competition in order to provide incentives for ISPs to deploy better DSL switches:

The strategic view of the market that Ofcom have embraced has shifted over time in response to changing technology, market circumstances and expectations regarding the prospects for different forms of competition. Whilst the underlying strategic view is not always explicit it can be inferred, and understating how strategy has shifted is helpful in understanding how existing policy has arisen and whether it should change.

*In the period to 2004, Oftel pursued a strategy of promoting platform competition, rather than for example local loop unbundling. In 2005 Ofcom acknowledged this, noting that:*²⁰⁵

“It is clear that encouraging investment in competing access networks was a key Oftel objective in determining the level of the LLU and WLR [wholesale line rate] charges.” Paragraph 4.1

*In 2004, Ofcom wrote that it:*²⁰⁶

“...considers that LLU has a significant part to play in establishing competitive broadband markets and is therefore committed to ensuring that appropriate regulation is put in place to provide the most positive environment for the success of LLU.” Paragraph 7.12

*The Ofcom Strategic Review of Telecommunications concluded with a shift in strategy with greater focus on promoting competition at the deepest level of infrastructure possible (and unbundling i.e. MPF in particular) and recognising that there are trade-offs in promoting all kinds of competition in equal measure.*²⁰⁷

“we concluded that the competing end - to - end infrastructures that would be likely to be sustainable in the UK in the medium term would be insufficient to deliver effective competition. We therefore adopt the principle that regulation should promote competition at the deepest level of infrastructure where it is likely to be effective and sustainable.” Paragraph 3.14

“Regulation can promote each of these kinds of competition, but we pointed out in Phase 2 that there are trade - offs involved: if regulation tries to promote all these kinds of competition in equal measure, it is likely to be unsuccessful.” Paragraph 4.4

In other words there may be benefits from taking a strategic view of market development rather than adopting a strictly neutral approach since (if the view is correct) the costs associated with trade-offs can then be minimised. There was deemed to be a need to steer the market in particular direction, this being towards MPF - based competition in voice and what we now term Current Generation Access.

Regarding the rental charge for MPF, Ofcom concluded a review into the costs of local access services in 2005 which introduced a number of changes to the estimate of costs. This led to a reduction in the estimated cost for MPF, and prices fell 24 percent in August 2005. The creation of significant price differential between MPF and WLR provided a clear impetus to competition based on this input, and MPF volumes have since increased from 226,000 in 2006/7 to 7.6 million lines by December 2013.²⁰⁸

This is the sort of operational minutiae that preoccupies regulators under the LLU regime; there are several ways to unbundle the loop, so the question of which method is best often overshadows questions of the end user's maximum utility and value.

First-generation wire leasing is a barrier to the deployment of next-generation Vectored DSL, so it would have been better for Ofcom to move competitive ISPs Talk Talk and Sky away from MPF and toward WLR (bitstream). This does seem to be the current direction:

The shift to active products has been driven in the first instance by the different network technology and topology for fibre which makes unbundling relatively less attractive. Active products may also, in contrast to the situation with unbundling and ADSL, offer the best prospects for innovation and competition...²⁰⁹

U. K. is stuck with DSL for the time being because BT's pre-tax free cash is too low to support FTTH deployment without massive subsidies. The first instance of such subsidies was a controversial £530m rural broadband grant, followed by an additional (and also controversial) £1.2bn grant to upgrade urban homes and businesses.²¹⁰



Figure 109: People of Borwick installing their own network. Source: Motherboard.

U. K. has managed to navigate a path through the complexities of local loop unbundling, limited facilities-based competition between cable and DSL, and massive subsidies to a well-performing and widely used wired infrastructure. The policy question is to what extent U. K. has managed to encourage its formerly government owned telecom, BT, to comply with regulators' wishes in its self-interest rather than in anticipation of subsidies. To the extent that BT is subsidy-driven, it effectively operates as an arm of

the government, despite its putative private status.

U. K.'s predominately urban/suburban population distribution has helped as well; some rural Britons have taken matters into their own hands rather than waiting for BT to wire their villages. In the parish of Borwick near Lancaster, citizens have formed a community broadband project called B4RN (Broadband for the Rural North). The people of Borwick are digging their own trenches, laying fiber, and mastering the art of fiber splicing in order to construct a gigabit network.²¹¹ B4RN will be the fastest residential network in Europe.

BT has been granted a three-year regulatory holiday from Ofcom's price controls for its FTTH network; this is called "pricing flexibility" in U. K. and it's consistent with the "contingent model's" practiced use of limits on competitive access to advanced facilities.²¹² Contingent model states allow easy access to legacy facilities, and much more restricted access to advanced ones. This becomes clearer when we examine Germany.

According to IHS, BT and the U. K. government have committed €5B to increase broadband capacity:

*In 2013, the UK government committed to ensuring that 95 percent of UK homes receive speeds of at least 24Mbit/s by 2017. Coupled with BT's investment in FTTC and FTTH broadband, intended to cover nearly 20 million homes by the end of 2014, over €5 billion is being spent on upgrading the UK's broadband infrastructure.*²¹³

BT's contribution will increase the firm's already-substantial debt, but interest in using the Internet and traffic loads in U. K. are high compared to its EU partners.

v. Germany

Like the U. K. and the rest of the EU, Germany's regulators struggle with European Commission mandates to provide competition over a common wire plant while also trying to promote the investment-driven technology dynamics that enable broadband services to improve cost/performance ratios on a consistent basis. And like the U. K. (and unlike most of the EU) Germany has substantial cable broadband deployment - cable is available to ~55 percent of the German people today.²¹⁴ Consequently, the history of broadband regulation in Germany is marked by a series of legal disputes between the EU and the German regulatory body, the Federal Network Agency (BNetzA).

In 2007, the German parliament granted Deutsche Telekom (DT) a three-year holiday from the line-sharing mandate for VDSL in a move intended to spur deployment of an advanced broadband technology. European Commission officials criticized the law and warned of legal action: "the granting of regulatory holidays to incumbent operators is an attempt to stifle competition in a crucial sector of the economy, and in violation of EU telecom rules in place since 2002."²¹⁵ In 2009, the European Court of Justice agreed with the EC and struck down the German law.²¹⁶

But by that time, DT had reached leasing agreements with Vodafone and 1x1 to open the VDSL network to competition on the condition that sharing went both ways, between DT's copper lines and competitors' fiber in both directions. Thus, DT is able to share competitors' fiber to lower its costs just as competitors are able to use DT's copper to lower their costs.

Both sides of these agreements follow the "contingent model" in which access requires a minimum number of lines, as is the case for fiber access in Japan. This form

of bilateral and contingent network access has become the norm in Germany and is active in the current push to provide greater Vectored DSL and FTTH deployment in that country.²¹⁷ It has also expanded into the mobile space, where access to fiber or fiber-like tower backhaul is a critical factor.²¹⁸ It has spread to the U. K. and other parts of Europe as well. The access that DT offers to its copper lines can also be obtained as either Data Link Layer (Layer 2 in the OSI model) frame streams or Network Layer (Layer 3) packet streams.

The push to raise speeds over DSL with VDSL, Vectored DSL, and FTTH in Germany is motivated in large part by the desire of DT to close the performance gap between DSL and cable. Since 2008, Germany has had the largest cable footprint in Europe; see:

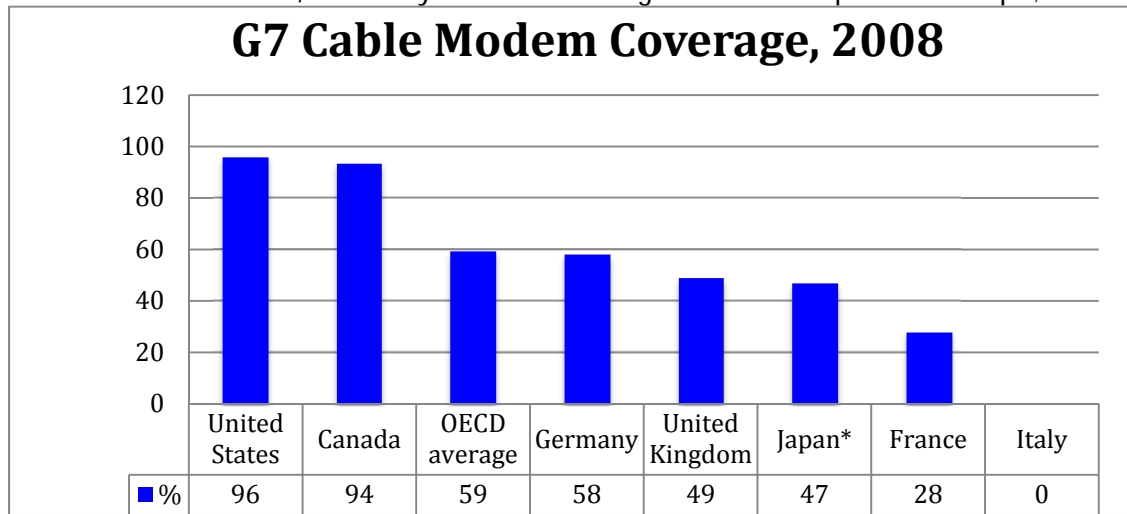


Figure 23

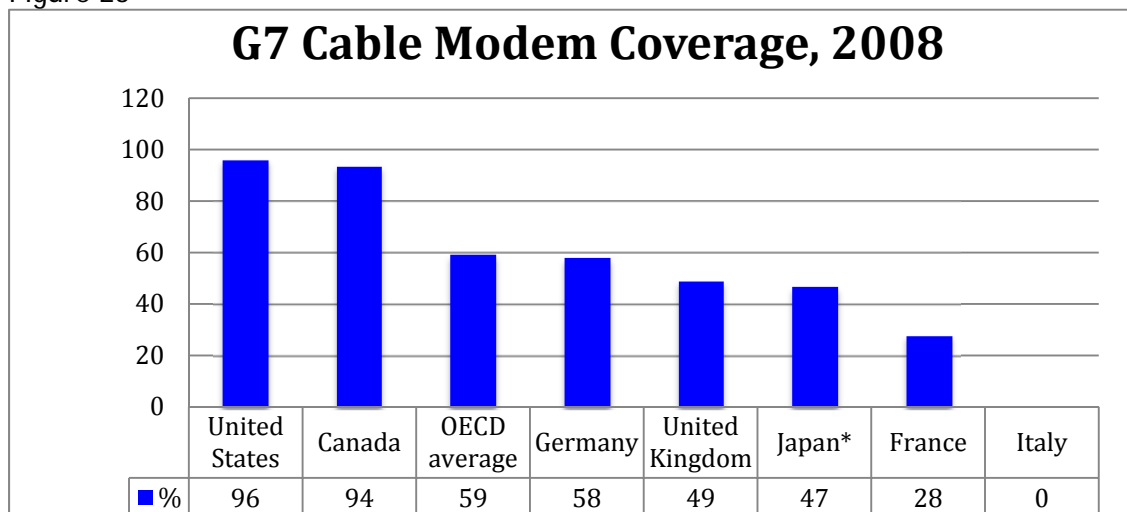


Figure 23: G7 Cable Modem Coverage in 2008. Source: OECD and *JCTEA

Ironically, DT originally built the German cable TV system, but it was forced to sell it in 2003 in order to reduce debt and to finance expansion into mobile.²¹⁹ The sale was complicated by the fragmentation of the cable network imposed by the German competition authority to deal with market concentration fears stemming from control of both cable and DSL by a common entity, albeit one in which government was a significant stakeholder:

A distinctive feature of the German cable infrastructure is its fragmentation into independently owned and operated cable franchises. The infrastructure is split into 4 different network levels. Level 1 comprises the production of TV- and Radio-Programming. Level 2 contains the transmission from production sites to reception-stations in the networks of level 3 operators. Level 3 is the actual backbone network of coaxial cable that extends to the customer premises. Level 4 encompasses the last meters from the curb to the cable outlet in the customer's house/apartment.

DT formerly held 80 percent of level 3 and around 30 percent of level 4 infrastructure. Because the EU was considering legislation demanding the institutional separation of the cable and telecommunications business of former monopolies, DT in 1998 established a holding company for its cable activities. Of the 9 Cable Regions in the holding, DT sold three by the end of 2001. The cable infrastructure of the Bundesländer Nordrhein-Westfalen (NRW) and Baden-Württemberg (BW) were purchased to 55 percent and 45 percent by Callahan Associates International LLC, that operate under the company name "ish" in Germany. The cable infrastructure in Hessen now belongs to 65 percent to a consortium around Klesch & Company, a London-based private equity firm. The company name for the Klesch products is "iesy". The remaining shares continue in the possession of DT, however, the investors have the option to obtain the DT shares. The conflict of interest for DT concerning the success of the cable operators in voice-telephony and Internet access is obvious.²²⁰

Arguably, the contingent model would not have emerged in Germany without BNetzA's willingness to disobey the EC and chart a course that made more sense for the German people than did the EC's "one size fits all" line sharing mandate. The contingent model responds to local market conditions, in other words. When implemented in a bilateral fashion, contingent access becomes similar to the way that Internet operators negotiate interconnection agreements: on the basis of equal value.

Like the rest of Europe, and indeed, the rest of the developed world, Germany has a national broadband plan ("The Federal Government's Broadband Strategy") addressing broadband performance goals, spectrum policy, uptake programs, and rural networks and the subsidy programs necessary to support them.²²¹

The Strategy, developed in 2009, targets 50 Mbps broadband availability to 75 percent of German homes by 2014 and emphasizes "synergies in construction projects". In terms of competitors, the Strategy singles out France, Japan, and the U. S., and mentions no other nations.

Among the measures the Strategy avows to pursue, one of great interest concerns the need to change European policy:

Measure 11: Requirements related to incentives and investment stimulus in the EU regulatory framework.

At a European level, the Federal Government is seeking clarity within the EU telecommunications regulatory framework in order to achieve speedy and reliable modernization of networks.

- *The additions sought to the framework directive should offset the investment risk by enabling innovative and intelligent cooperation*

mechanisms that will adequately spread the investment risk among the network operators and between the network operators and businesses requiring network access. The Federal Government will campaign at European level and among Member States for this type of incentive mechanism and the creation of an investment-friendly environment. Once these factors are in place, it will be possible to generate enormous sums that must be made available in the coming years for modernizing telecommunications networks. In the interests of competition, the Federal Government will monitor the incentive mechanisms to ensure that network access is available to all and that the principle of non-discrimination is preserved. The regulations must not be allowed to distort market competition.

- *The Federal Government is also advocating long-term planning certainty and consistent regulatory policy. Specifications made by the regulatory bodies must be guaranteed to be valid for more than three years and thus endure longer than the validity of a market analysis, if necessary. A stable regulatory climate is crucial for the necessary investment in next-generation networks.*²²²

This is a clear and sensible admission by a European government that the European local loop unbundling policy retards network progress in nations with competitive broadband facilities unless it is modified by contingent and bilateral agreements.

To the extent that Europe has been successful in deploying advanced broadband, it has departed from the standard EC model.

According to IHS, DT has committed substantial investment in coming years:

*Deutsche Telekom made headlines when it committed in 2012 to a headline investment of €30 billion in high speed broadband technology in the years to 2015. A significant proportion of Deutsche Telekom's investment is actually committed to the US for LTE build-out, but €6 billion is still being devoted to next-generation broadband rollout in Germany. Deutsche Telekom intends to ensure that 65 percent of homes are covered by its fibre-to-the-cabinet (FTTC) network by 2016, with new 'vectoring' technology being deployed to raise transmission rates to 100Mbit/s.*²²³

Most of DT's increased investment will be spent in the U. S., however.

vi. France

France has always had a curious relationship with the Internet. On the one hand, the fundamental ideas in Internet architecture were developed in France by the researchers who created the CYCLADES network in the early 1970s.²²⁴ CYCLADES as a government-funded research project, and what the government funds it can also de-fund: CYCLADES was shut down in 1981 under pressure from France Telecom.

On other, France's participation in and access to today's Internet are decidedly sub-standard, as the deployment and performance data indicate. France stands out as the second largest market for DSL (92 percent of its wired broadband connections) and for the equal speed of its wired and mobile networks. Performance parity is more an indictment of the wired networks than an indication that its mobile ones are excellent.

France has devised two national broadband plans. The Sarkozy government released the first plan in 2008, the *French Digital Plan 2012*. According to its architect, this plan would have enabled universal service and FTTH:

*High speed access at 512 Kbps for less than 35 euros a month should become a universal service. An RFP could be issued in early 2009 to allocate this universal service to an operator. "Each French citizen, wherever he lives, will have a right to high speed access," Besson said. Elaborating further on infrastructure, Besson asserts that France is "now moving to ultra broadband networks and 4 million households will be connected through FTTH access by 2012, with €10 billion of investments for the next 10 years."*²²⁵

While the universal service part has come to pass, FTTH continues to be very rare in France; the planned investment of €10B didn't actually happen. The Hollande government released its own plan in 2013, *France Très Haut Débit* (THD), echoing the Sarkozy plan's ambitious goals and doubling the promised funding to €20B.²²⁶

While German regulators spar with the EC over unbundling regulations that appear calculated to dampen investment, France has been in conflict with Brussels for over a decade on the issues of its non-compliance with EC directives forbidding state aid to business.²²⁷ In one instance, the EC penalized France for a bailout of France Telecom after it over-extended itself in the Internet bubble, and in another the EC opened an inquiry into excessive telephone termination fees it awarded to Iliad's Free.fr service.²²⁸

Free.fr is a darling of American community broadband hawks who fail to appreciate the fact that ARCEP gave Free Mobile extraordinary concessions because it was desperate to create the appearance of dynamism in its stagnant mobile broadband market. For all practical purposes, Free Mobile was created by regulators and is supported by subsidies paid to Iliad by competitors, like a U. S. rural telephone company. Objectively, its service is low quality; according to ARCEP, Iliad's Free Mobile service "got significantly worse results on a large number of indicators" and has the lowest overall quality of any mobile service in France.²²⁹

It's not terribly surprising that France should develop national plans that rely so heavily on subsidies for very advanced technologies while its actual wired networks languish. France has developed an "innovation by permission culture" where network operators are reluctant to act without direct financial support from the government; broadband operators weren't allowed to offer VDSL in France until 2013, as the central government feared it would reduce the appetite for FTTH.²³⁰

With the government calling the shots for the broadband industry and the planners focused on lofty but impractical goals a generation or more beyond current needs, it's no wonder that France racks up low scores on Advanced Broadband. One sign of pragmatism does emerge from the Hollande plan, however: the government will spend €70M on satellite broadband targeted to rural areas.²³¹ It's not clear those areas will actually be in France, but they will be served by French-made satellites; state aid, once again.

By relying on grandiose plans that it probably will never implement, France has created another policy paradigm, the "Utility Model", in which the regulator seeks to be all-powerful by controlling the purse and micromanaging industrial dynamics.

IHS identifies massive potential investment in France:

In 2013, the French government set out plans to invest €20 billion of public and private funds in next-generation fixed and mobile broadband, aiming to cover half of the population by 2017, with the remaining homes covered within a further five years. “Crucially, the government’s plans have stratified investment, asking ISPs to fund urban coverage, while providing a mixture of state and local government funding to ensure that semi-urban and rural areas are connected,” Broughton said.²³²

History suggests a degree of skepticism should be applied to this announcement; the austerity measures that doomed prior plans still rule government decision-making in France.²³³

My assertion that France and Italy practice a different form of regulation than other EU nations is not entirely novel; Tsatsou and Jordana have made similar observations about the diversity of regulatory policies in the EU: *“Research identified a “Southern European” interventionist approach to telecommunications regulation correlated with “cultural affinities” of the countries in that region.*^{234 „235}

vii. Italy

The policy story in Italy is virtually the same as in France: the nation is highly rural, was poorly connected prior to broadband, and is hemmed in by policies discouraging cable TV. In 1999, only five percent of Italian homes were passed by cable TV, but mobile phones were more common than in any other G7 nation, at 53 subscribers per 100 population. As in Germany, cable regulations penalized size, so all cable networks were poorly capitalized.²³⁶ The Italian national broadband plan, *Italia Digitale* has always placed great stock by FTTH; by 2008 there was still no cable modem service in Italy.

FTTH was never deployed outside a few cities, and had not even reached 12 percent coverage by 2012. Italy had the highest 3G coverage among the European contingent of the G7 in 2009, 92 percent, but didn’t begin to move on LTE until 2012. It also didn’t move on VDSL until 2012 when its 4.5 urban percent coverage was dwarfed by 14.3 percent *rural* coverage and 47 percent urban coverage in U. K.; but it did begin LTE and VDSL deployment ahead of France.

Italy’s current target for broadband infrastructure simply follows the *Digital Agenda for Europe*: universal connectivity at a minimum of 30 Mbps, with at least 50 per cent of households passed by Internet connections above 100 Mbps by 2020. Italy proposes to leverage private investment where possible, and offers three forms of subsidy otherwise: direct support, public/private partnerships, and incentives. There are certain common assumptions:

All three models predict the reuse of existing infrastructure of public and private property (ducts and existing infrastructure of multi-utility operators or local), which is defined as the acquisition of rights of use. In the case of re-use of existing infrastructure, please note that wholesale access obligations are not subject to restrictions, but must be guaranteed for at least 7 years.²³⁷ [Note: Google translation]

The Italian plan appears light on specifics; but this may be due to the relatively small number of documents available in English, but there is not much to found in the usual places. It’s telling that Italy devises and articulates three forms of subsidy; it has no faith in free market solutions at all. Like France, Italy follows the “Utility Model” of

grandiose but unrealized dreams. Where North America, Western Europe, and Japan write prose, Southern Europe writes poetry.

IHS reports that Italy has humble plans for government investment in wireline upgrades:

At the end of 2013, Telecom Italia ended speculation about its plans for next-gen broadband rollout by committing to significant investment in next-gen broadband – encompassing €1.8 billion in fixed access, and €0.9 billion in expanding its next-gen mobile network. The company aims to cover over half of the population with its ‘ultrabroadband’ by 2016.²³⁸

This is a small but achievable goal for most nations of Italy's size.

8. Summary of Results

Now that we've analyzed the objective data and reviewed the policy background, we can construct a reasonable scorecard regarding the effectiveness of national policies. This exercise necessarily involves weighting the mass of data we're uncovered, but as most of the raw data is presented in its original form, other researchers are free to construct the own ratings without digging too hard for objective information.

The first thing to do is to discard the obvious 1 – 7 ranking system that would seem to be intuitive for a group of seven nations. A simple ranking system creates artificial scarcity, and we don't want any of that in a broadband study. Analysis of the raw data suggests that most measurements show a clustering of nations into three groups in which differences within the group are less pronounced than those between groups.

On cable modem coverage, for example, the U. S. and Canada each have more than 90 percent; Germany, U. K. and Japan are close to 50 percent, and France and Italy are below 30 percent. On FTTx coverage, Japan has 90 percent; the U. S., Italy, Canada and France range from 23 to 6.5 percent, and Germany and U. K. are below three percent. I will therefore score each category high, medium, and low, and allow the number of nations in each group to be determined by the spreads within the data.

For all practical purposes, broadband at the basic level of either some form of DSL, cable, or satellite plus 3G is close enough to universal to no longer be an issue. Therefore, the scorecard will focus on Advanced Broadband and to a limited extent on Pervasive Broadband (FTTH and LTE Advanced). Specific speeds and financials are embedded in the Value Index, so they're not repeated in the scorecard.

	Rural	NGA	LTE	Smart phone	Mob >10M	Mob >4M	Use	Mob use	BW/ Pr	MBW/ Pr	Inv	AVG
United States	1	2	1	1	2	2	1	2	1	2	1	1.45
Japan	3	1	2	2	1	1	2	1	1	1	2	1.55
Canada	1	2	1	2	2	1	1	2	2	2	1	1.55
United Kingdom	2	2	3	1	2	1	2	2	1	1	3	1.82
Germany	2	2	2	2	3	3	3	3	2	2	3	2.45

France	2	3	3	2	3	1	3	3	2	3	2	2.45
Italy	3	3	3	3	3	1	3	3	3	3	2	2.73

Figure 110: G7 Broadband Scorecard (lower is better)

The data come from the following figures:

Rural: Figure 18: G7 Rural persons per sq. km. arable land. Source: World Bank

NGA: Figure 30: G7 NGA coverage and urban population 2012. Sources: EC, NTIA, MIC, CRTC, World Bank.

LTE: Figure 35: LTE Coverage in 2012. Source: EC, NTIA, CRTC. *Japan estimated.

Smartphone: Figure 41: G7 Smartphone Adoption. Source: BAML Wireless Matrix and Mobile Planet by Google.

>10M: Figure 51: Percent Connections >10Mbps Q1 2013-14. Source: Akamai.

Mob >4M: Figure 55: G7 Mobile Broadband Speed 1Q 2014. Source: Akamai

Usage: Figure 74: Projected Internet traffic in gigabytes per household per month. Sources: Cisco, World Bank, and NationMaster.

Mob Usage: Figure 75: G7 estimated mobile data usage per household. Sources: Cisco, World Bank, and Nationmaster.

Bandwidth/Profit: Figure 84: G7 Wired broadband end user bandwidth price in dollars of profit. Source: Infonetics, Point Topic, Akamai, Cisco.

Mobile Bandwidth/Profit: Figure 92: G7 Mobile Broadband Bandwidth Price in Dollars of Provider Profit. Source: author calculations on data from Ookla, Cisco, BAML.

Mobile Bandwidth/Revenue: Figure 93: G7 Mobile Broadband Bandwidth Price in Dollars of Provider Revenue. Source: author calculations on data from Ookla, Cisco, BAML and Infonetics.

Inv: Figure 104: G7 Telecom Investment per capita. Source: ITU

Avg: Average of all indicators.

The resulting ranking reflects regulatory models: Pioneer nations do best, Contingent states are next best, and Utility nations are worst.

9. Conclusion

We can almost predict the standings in the G7 Broadband Scorecard on the basis of cable TV coverage in 1999; all nations except Italy retain their positions from that chart (Figure 20).

This effect is not because of reliance on cable in today's broadband networks as much as it is a reflection of the role of competition in both the facilities realm and the policy sphere.

Italy failed to deploy cable modem broadband, so it lost the competitive dynamic and slipped to last place, while Japan built a cable network and used it as the vehicle for its first broadband connections (page 114). Robust competition between DSL and cable in the U. S. and Canada obviated the need for those countries to impose local loop

unbundling, and satellite and terrestrial wireless services with high capacity offered a meaningful universal service solution.

Japan, U. K., and Germany responded to less robust but still substantial competition from cable by upgrading telco networks to VDSL (Figure 32). LLU regulations in these countries follow the “contingent model” that discourages very small providers and allows incumbents and competitive carriers to negotiate mutually beneficial terms of interconnection.

Laggard nations France and Italy have formulated grand plans that can only be implemented on the backs of massive taxpayer subsidies that have not been forthcoming and may very well run afoul of EC prohibitions on state aid to telecoms and EC austerity policy if they were actually implemented.

The roles played by cable, satellite, and advanced mobile networks have less to do with the technical capabilities of these technologies (FTTH will always offer higher capacities than copper- or radio-based networks) than with their ability to energize competitive dynamics in the broadband marketplace. While FTTH will always be faster, the capacity of the last mile network is not the most important factor in the end user’s experience of the web, web server capacity is (see: Browsing Speed). Consequently, pursuing the number one ranking in network connection speed is an unworthy goal.

The best way to assess the success of a broadband strategy is on the basis of coverage by advanced technologies, usage of advanced technologies, and the consumer value index that divides bandwidth by profit. This index recognizes that costs of service are not as low in prairie nations as they are in high-rise nations.

On the holistic basis, the competitive “Pioneer Model” employed by the U. S. and Canada outperforms the “Contingent Model” used in Japan, U. K., and Germany, and the contingent model outperforms the single infrastructure “Utility Model” utilized by France and Italy.

The menu of choices for policy makers is relatively simple: if we want a dynamic broadband marketplace in which citizens enjoy high performance networks at reasonable prices, it’s necessary for regulators to be humble enough to allow the competitive dynamic to unshackle human ingenuity. If we’re content to follow the leader and move more slowly, we can adopt the Contingent Model with a micro-managing regulator. If we want stagnation, we can follow the Franco-Italian “almighty regulator” approach and bemoan our lack of progress.

The data point unambiguously to the proper path.

Acknowledgements

The author is grateful for the generous encouragement, advice and guidance of Dr. Everett M. Ehrlich and Dr. Jeffrey A. Eisenach in the preparation of this paper. He also thanks Guro Ekrann, Anthony Paranzino, and Sarah Fellay for their indispensable research assistance. All errors and omissions are the sole handiwork of the author.

Endnotes

¹ Robert W. Crandall, Jeffrey A. Eisenach, and Robert E. Litan, "Vertical Separation of Telecommunications Networks: Evidence from Five Countries," *Federal Communications Law Journal* 62, no. 3 (June 1, 2010),

http://papers.ssrn.com/sol3/papers.cfm?abstract_id=1471960.

² Raul L. Katz, "The Impact of Broadband on the Economy: Research to Date and Policy Issues" (presented at the 10th Global Symposium for Regulators, Senegal, November 10, 2010), <https://www.itu.int/ITU-D/treg/Events/Seminars/GSR/GSR10/documents/GSR10-ppt1.pdf>; William H. Lehr et al., "Measuring Broadband's Economic Impact" (33rd Research Conference on Communication, Information, and Internet Policy (TPRC), September 23, 2005), http://www.andrew.cmu.edu/user/sirbu/pubs/MeasuringBB_EconImpact.pdf; ITU Telecommunication Development Sector, *Impact of Broadband on the Economy* (Geneva, Switzerland: ITU, 2012), http://www.itu.int/ITU-D/treg/broadband/ITU-BB-Reports_Impact-of-Broadband-on-the-Economy.pdf; Christine Zhen-Wei Qiang, *Broadband Infrastructure Investment in Stimulus Packages: Relevance for Developing Countries* (Washington, DC: The Worldbank, January 1, 2009), <http://documents.worldbank.org/curated/en/2009/01/10727569/broadband-infrastructure-investment-stimulus-packages-relevance-developing-countries>; World Bank and World Bank, *2009 Information and Communications for Development: Extending Reach and Increasing Impact* (Washington, D.C: World Bank, 2009).

³ ITU Telecommunication Development Sector, *Impact of Broadband on the Economy*.

⁴ Beñat Bilbao-Osorio et al., *The Global Information Technology Report 2013 Growth and Jobs in a Hyperconnected World* (Geneva, Switzerland: World Economic Forum, 2013), http://www3.weforum.org/docs/WEF_GITR_Report_2013.pdf; Economist Intelligence Unit, "Digital Economy Rankings 2010: Beyond E-Readiness," June 2010, http://www-935.ibm.com/services/us/gbs/bus/pdf/eiu_digital-economy-rankings-2010_final_web.pdf.

⁵ Bilbao-Osorio et al., *The Global Information Technology Report 2013 Growth and Jobs in a Hyperconnected World*, page 7.

⁶ FCC Office of Engineering and Technology and Consumer and Governmental Affairs Bureau, *Measuring Broadband America - 2014*, Measuring Broadband America (Washington, DC: Federal Communications Commission, 2014), <http://www.fcc.gov/reports/measuring-broadband-america-2014>.

⁷ Net Index from Ookla, "Global Value Index," *Ookla*, accessed July 29, 2014, <http://www.netindex.com/value/>.

⁸ OECD, *OECD Communications Outlook 2003* (OECD Publishing, 2003), http://www.keepeek.com/Digital-Asset-Management/oecd/science-and-technology/oecd-communications-outlook-2003_comms_outlook-2003-en.

⁹ OECD, *OECD Factbook* (OECD Publishing, June 2014), <http://www.oecd.org/publications/factbook/>

¹⁰ Ibid.

¹¹ Richard Bennett, Luke A. Stewart, and Robert D. Atkinson, *The Whole Picture: Where America's Broadband Networks Really Stand* (Washington, DC: Information Technology and Innovation Foundation, February 12, 2013), <http://www.itif.org/publications/whole-picture-where-america-s-broadband-networks-really-stand>.

¹² Ibid., page 60.

¹³ Ibid.

¹⁴ World Bank, *The Little Green Data Book 2011* (Washington, D.C.: World Bank, 2011).

¹⁵ Ibid.; Aemen Lodhi et al., "Using PeeringDB to Understand the Peering Ecosystem," *ACM SIGCOMM Computer Communication Review (CCR)* 44, no. 2 (April 2014): 21-27.

¹⁶ CRU International Ltd, *CRU Monitor: Optical Fibre and Fibre Optic Cable* (London, September 2012), <http://www.crugroup.com>.

¹⁷ OECD, *OECD Communications Outlook 2003*.

¹⁸ Ibid.

¹⁹ World Bank, "Mobile Cellular Subscriptions (per 100 People)," *The World Bank*, accessed May 26, 2014, <http://data.worldbank.org/indicator/IT.CEL.SETS.P2?page=2>.

²⁰ "List of Satellites at Geostationary Orbit," satellite information, *Satbeams*, accessed May 27, 2014, <http://www.satbeams.com/satellites>.

²¹ Eli M. Noam, "Beyond Liberalization II: The Impending Doom of Common Carriage," *Telecommunications Policy*, March 15, 1994, <http://www.columbia.edu/dlc/wp/citi/citinoam11.html>.

²² Michael Saylor, *The Mobile Wave: How Mobile Intelligence Will Change Everything*, First Da Capo Press paperback edition (Boston, MA: Da Capo Press, a member of the Perseus Books Group, 2013); Susan P Crawford, *Captive Audience: The Telecom Industry and Monopoly Power in the New Gilded Age*, Kindle (New Haven [Conn.]: Yale University Press, 2013); Jeremy, Cederholm, Dan, Kissane, Erin Keith et al., *A Book Apart: Brief Books for People Who Make Websites*. (New York: Book Apart, 2010).

²³ Louise Ridley, "Mobile Is the 'First Screen' for Half of 18-34s," *Media Week*, October 21, 2013, <http://www.mediaweek.co.uk/article/1217158/mobile-first-screen-half-18-34s>.

²⁴ Bronwyn Howell, "Government-Subsidized Fiber: Careful What You Wish for," *Tech Policy Daily*, March 26, 2014, <http://www.techpolicydaily.com/communications/government-subsidized-fiber-careful-wish/>. Jeffrey Eisenach, "Australia's Failed Experiment in Government-Owned Broadband," *Tech Policy Daily*, March 6, 2014, <http://www.techpolicydaily.com/communications/australias-failed-experiment-government-owned-broadband/>.

²⁵ NTIA and FCC, *Broadband Availability in Urban vs. Rural Areas*, Broadband Statistics Report (Washington, DC, July 2013), http://www2.ntia.doc.gov/files/broadband-data/Broadband_Availability_in_Rural_vs_Urban_Areas_DEC_2012.pdf.

²⁶ OECD, "OECD Broadband Portal," *OECD*, January 9, 2014, <http://www.oecd.org/internet/broadband/oecd broadband portal.htm>.

²⁷ Hiroshi Asami, "Cable TV in Japan: Competitive Status in Full Digital Age; Migration for IP Video," 2010, <http://www.catv.or.jp/jctea/english/standards/pdf/CableinJapan.pdf>.

²⁸ OECD, "OECD Broadband Portal."

²⁹ NTIA and FCC, *Broadband Availability in Urban vs. Rural Areas*, July 2013.

³⁰ Point Topic, *Broadband Coverage in Europe in 2012* (European Commission DG Communications Networks, Content & Technology, 2013), http://ec.europa.eu/information_society/newsroom/cf/dae/document.cfm?doc_id=3647.

³¹ Canadian Radio-television and Telecommunications Commission, "Communications Monitoring Report 2013: Broadband Availability and Adoption of Digital Technologies," government data, *CRTC*, (January 15, 2014), <http://www.crtc.gc.ca/eng/publications/reports/policymonitoring/2013/cmr6.htm>.

³² OECD, "OECD Broadband Portal."

³³ Ibid.

³⁴ Ibid.

³⁵ NTIA and FCC, *Broadband Availability in Urban vs. Rural Areas*, July 2013.

³⁶ Ibid.

³⁷ Ibid.

³⁸ Ibid.

³⁹ Point Topic, *Broadband Coverage in Europe in 2012*.

⁴⁰ NTIA and FCC, *Broadband Availability in Urban vs. Rural Areas*, July 2013.

-
- ⁴¹ Ministry of Internal Affairs and Communications, *White Paper 2013: Information and Communications in Japan* (Tokyo: Ministry of Internal Affairs and Communications, 2013), <http://www.soumu.go.jp/johotsusintokei/whitepaper/eng/WP2013/2013-index.html>.
- ⁴² Canadian Radio-television and Telecommunications Commission, "Communications Monitoring Report 2013: Broadband Availability and Adoption of Digital Technologies."
- ⁴³ World Bank, "World Development Indicators: Rural Environment and Land Use," data, *The World Bank*, (2014), <http://wdi.worldbank.org/table/3.1>.
- ⁴⁴ NTIA and FCC, *Broadband Availability in Urban vs. Rural Areas*, July 2013.
- ⁴⁵ European Commission, "Broadband in Europe: Consumers Are Not Getting the Internet Speeds They Are Paying for," press release, accessed January 9, 2014, http://europa.eu/rapid/press-release_IP-13-609_en.htm.
- ⁴⁶ Christopher S. Yoo, *U.S. vs. European Broadband Deployment: What Do the Data Say?* (Philadelphia: Center for Technology, Innovation and Competition, June 2014).
- ⁴⁷ Point Topic, *Broadband Coverage in Europe in 2012*.
- ⁴⁸ NTIA and FCC, *Broadband Availability in Urban vs. Rural Areas*, July 2013.
- ⁴⁹ Canadian Radio-television and Telecommunications Commission, "Communications Monitoring Report 2013: Broadband Availability and Adoption of Digital Technologies."
- ⁵⁰ John Jannarone, "What John Malone Wants to Own Outside the US," *CNBC*, July 11, 2014, <http://www.cnn.com/id/101830388#>.
- ⁵¹ Point Topic, *Broadband Coverage in Europe in 2012*.
- ⁵² NTIA and FCC, *Broadband Availability in Urban vs. Rural Areas*, July 2013.
- ⁵³ Canadian Radio-television and Telecommunications Commission, "Communications Monitoring Report 2013: Broadband Availability and Adoption of Digital Technologies."
- ⁵⁴ Asami, "Cable TV in Japan: Competitive Status in Full Digital Age; Migration for IP Video."
- ⁵⁵ Point Topic, *Broadband Coverage in Europe in 2012*.
- ⁵⁶ NTIA and FCC, *Broadband Availability in Urban vs. Rural Areas*, July 2013.
- ⁵⁷ Ministry of Internal Affairs and Communications, *White Paper 2013: Information and Communications in Japan*.
- ⁵⁸ Phil Goldstein, "MetroPCS Launches LTE in Las Vegas, Promises More Markets 'Soon' -," *FierceWireless*, September 21, 2010, <http://www.fiercewireless.com/story/metropcs-launches-lte-las-vegas-promises-more-markets-soon/2010-09-21>; Tom Pica, "Verizon Wireless 500 4G LTE Markets," *Verizon News Center*, June 27, 2013, <http://www.verizonwireless.com/news/2013/06/verizon-wireless-500-4G-LTE-markets.html>.
- ⁵⁹ Mary Brown, "Kevin Martin Is Right about DTV Spectrum Auction: Put Consumer Interests First," *Cisco Blogs*, July 27, 2007, http://blogs.cisco.com/gov/kevin_martin_is_right_about_dtv_spectrum_auction_put_consumer_interests_fir/.
- ⁶⁰ Point Topic, *Broadband Coverage in Europe in 2012*.
- ⁶¹ NTIA and FCC, *Broadband Availability in Urban vs. Rural Areas*, July 2013.
- ⁶² Canadian Radio-television and Telecommunications Commission, "Communications Monitoring Report 2013: Broadband Availability and Adoption of Digital Technologies."
- ⁶³ NTIA and FCC, *Broadband Availability in Urban vs. Rural Areas*, July 2013.
- ⁶⁴ AT&T, "AT&T Eyes 100 U.S. Cities and Municipalities for Its Ultra-Fast Fiber Network," Press Release, (April 21, 2014), http://about.att.com/story/att_eyes_100_u_s_cities_and_municipalities_for_its_ultra_fast_fiber_network.html.
- ⁶⁵ CenturyLink, "CenturyLink Expands Its Gigabit Service to 16 Cities, Delivering Broadband Speeds up to 1 Gigabit per Second," Press Release, *CenturyLink*, (August 5, 2014), <https://www.centurylink.com/fiber/news/centurylink-expands-gigabit-service-to-sixteen-cities.html>.

⁶⁶ Shalini Ramachandran, "Comcast Steps Up Its Game on Internet Speeds," *Wall Street Journal*, July 24, 2014, <http://online.wsj.com/articles/comcast-steps-up-its-game-on-internet-speeds-1406238911>.

⁶⁷ Jim Barthold, "Verizon Extends D.C. FiOS Wait, as AT&T-San Francisco Cabinet Battle Continues," *Fierce Cable*, May 9, 2014, <http://www.fiercecable.com/story/verizon-extends-dc-fios-wait-att-san-francisco-cabinet-battle-continues/2014-05-09>.

⁶⁸ Gig.U, "From Gigabit Testbeds to the 'Game of Gigs': The Third Annual Report of Gig.U," August 2014, <http://www.gig-u.org/cms/assets/uploads/2012/12/81714-Gig.U-Final-Report-Draft-1.pdf>.

⁶⁹ Maria Ranoia Alonso, "Gigabit Ethernet--The Core of the Network," *Printing Impressions*, January 1999, <http://www.piworld.com/article/gigabit-ethernet-the-core-network-18376/1>.

⁷⁰ David Weinberger, "Reason #554 We Need Gigabit Internet Connections," *Joho the Blog*, accessed August 19, 2014, <http://www.hyperorg.com/blogger/2014/08/16/reason-554-we-need-gigabit-internet-connections/>.

⁷¹ NTIA and FCC, *Broadband Availability in Urban vs. Rural Areas*, Broadband Statistics Report (Washington, DC, February 2014), <http://www.broadbandmap.gov/download/Broadbandpercent20Availabilitypercent20inpercent20Ruralpercent20vspercent20Urbanpercent20Areas.pdf>.

⁷² Bennett, Stewart, and Atkinson, *The Whole Picture: Where America's Broadband Networks Really Stand*, page 22.

⁷³ Pew Research Center's Internet & American Life Project, "Usage and Adoption," *Pew Research Center's Internet & American Life Project*, April 3, 2014, <http://www.pewinternet.org/2014/04/03/usage-and-adoption/>.

⁷⁴ OECD, "Ageing Populations : High Time for Action" (OECD, March 2005), <http://www.oecd.org/employment/emp/34600619.pdf>.

⁷⁵ Pew Research Center's Internet & American Life Project, "Internet User Demographics," *Pew Research*, January 2014, <http://www.pewinternet.org/data-trend/internet-use/latest-stats/>.

⁷⁶ OECD, *OECD Factbook*.

⁷⁷ OECD, "OECD Broadband Portal."

⁷⁸ Ibid.

⁷⁹ Victor Yip and Tony Zhang, "Telecommunications: Hong Kong" (Uobkayhian, June 18, 2012), <http://www.utrade.com.hk/en/blue-top/621201234347PM1468050.pdf>.

⁸⁰ Cisco Systems Inc., "Bandwidth Consumption and Broadband Reliability" (Cisco Systems, 2012), http://www.cisco.com/c/en/us/products/collateral/cloud-systems-management/prime-home/white_paper_c11-711195.html.

⁸¹ OECD, "OECD Broadband Portal."

⁸² World Bank, "Population (Total)," data, *World Bank*, (2014), http://data.worldbank.org/indicator/SP.POP.TOTL?order=wbapi_data_value_2012+wbapi_data_value+wbapi_data_value-last&sort=asc.

⁸³ NTIA and FCC, *Broadband Availability in Urban vs. Rural Areas*, July 2013.

⁸⁴ Economic Commission for Europe Statistical Division, Trends in Europe and North America 2001 (UN Economic Commission for Europe, NY, 2001), p. 74. Aggregates compiled by NationMaster, "Countries Compared by People > Average Size of Households. International Statistics at NationMaster.com," data, *Nation Master*, (2014), <http://www.nationmaster.com/country-info/stats/People/Average-size-of-households>.

⁸⁵ Point Topic, *Broadband Coverage in Europe in 2012*.

⁸⁶ Pew Research Center's Internet & American Life Project, "Internet User Demographics."

⁸⁷ Glen Campbell, "Global Wireless Matrix 4Q13" (Bank of America Merrill Lynch, January 8, 2014).

⁸⁸ Maeve Duggan and Aaron Smith, "Cell Internet Use 2013" (Pew Research Center's Internet & American Life Project, September 16, 2013), http://www.pewinternet.org/files/old-media//Files/Reports/2013/PIP_CellInternetUse2013.pdf.

⁸⁹ Tony Brown, "Customers Dumping Fibre for 4G in Japan," *Delimiter*, November 21, 2012, <http://delimiter.com.au/2012/11/21/customers-dumping-fibre-for-4g-in-japan/>.

⁹⁰ OECD, *OECD Factbook*.

⁹¹ Pew Research Center's Internet & American Life Project, "Usage and Adoption."

⁹² Ibid.

⁹³ Thom File, *Computer and Internet Use in the United States*, Population Characteristics (Washington, DC: U.S. Department of Commerce Economics and Statistics Administration U.S. Census Bureau, May 2013), U.S. Department of Commerce Economics and Statistics Administration U.S. CENSU. S. BU.

⁹⁴ Bennett, Stewart, and Atkinson, *The Whole Picture: Where America's Broadband Networks Really Stand*.

⁹⁵ John B. Horrigan, PhD, "The Essentials of Connectivity" (Comcast, March 2014), http://corporate.comcast.com/images/Final_IE_Research_Full_Paper.pdf.

⁹⁶ Jeff D. Saunders, Charles R. McClure, and Lauren H. Mandel, "Broadband Applications: Categories, Requirements, and Future Frameworks," *First Monday* 17, no. 11 (November 5, 2012), doi:10.5210/fm.v17i11.4066.

⁹⁷ Ibid.

⁹⁸ Damir Isovici, Gerhard Fohler, and Liesbeth Steffens, "Real-Time Issues of MPEG-2 Playout in Resource Constrained Systems," *Journal of Embedded Computing*, no. 3 (June 2004), http://www.ipr.mdh.se/pdf_publications/482.pdf.

⁹⁹ Alexander Podelko, "How Response Times Impact Business?," blog, *Performance Calendar*, (December 17, 2011), <http://calendar.perfplanet.com/2011/how-response-times-impact-business/>.

¹⁰⁰ Nicholas C. Zakas, "How Content Delivery Networks (CDNs) Work," *NCZOnline*, November 29, 2011, <http://www.nczonline.net/blog/2011/11/29/how-content-delivery-networks-cdns-work/>.

¹⁰¹ Tomas Horak, "Cisco TelePresence Application," 2010, <http://www.terena.org/activities/e2e/ws3/slides/101130-cisco-Tomas.pdf>.

¹⁰² Saunders, McClure, and Mandel, "Broadband Applications."

¹⁰³ Federal Communications Commission, "WIRELINE COMPETITION BUREAU RELEASES CONNECT AMERICA COST MODEL ILLUSTRATIVE RESULTS USING HIGHER SPEED BENCHMARK" (Federal Communications Commission, June 17, 2014), https://apps.fcc.gov/edocs_public/attachmatch/DA-14-833A1.pdf.

¹⁰⁴ HTTP Archive, "Trends," Internet Research, *HTTP Archive*, (May 15, 2014), <http://httparchive.org/trends.php>.

¹⁰⁵ Netflix, "USA ISP Speed Index Results," Netflix ISP Speed Index, *Netflix*, accessed May 30, 2014, <http://ispspeedindex.netflix.com/usa>.

¹⁰⁶ Akamai, "State of the Internet," archive, *State of the Internet*, accessed February 1, 2013, http://www.akamai.com/stateoftheinternet/?WT.ac=soti_banner.

¹⁰⁷ Ibid.

¹⁰⁸ Ibid.

¹⁰⁹ Ibid.

¹¹⁰ Cyrus Farivar, "DC Think Tank Tells Americans That Their Broadband Is Really Great," technology tabloid, *Ars Technica*, (February 13, 2013), <http://arstechnica.com/business/2013/02/dc-think-tank-says-state-of-us-broadband-is-good-and-getting-better/>.

-
- ¹¹¹ "Slow-Start," *Wikipedia, the Free Encyclopedia*, accessed May 30, 2014, <http://en.wikipedia.org/wiki/Slow-start>.
- ¹¹² Cyrus Farivar, "DC Think Tank Tells Americans That Their Broadband Is Really Great," tech tabloid, *Ars Technica*, (February 13, 2013), <http://arstechnica.com/business/2013/02/dc-think-tank-says-state-of-us-broadband-is-good-and-getting-better/>.
- ¹¹³ FCC's Office of Engineering and Technology and Consumer and Governmental Affairs Bureau, *2013 Measuring Broadband America: February Report*, Measuring Broadband America (Washington, DC: Federal Communications Commission, February 2013), <http://transition.fcc.gov/cgb/measuringbroadbandreport/2013/Measuring-Broadband-America-feb-2013.pdf>.
- ¹¹⁴ SamKnows Limited, *Quality of Broadband Services in the EU - SamKnows Study on Internet Speeds (second Report)* (Brussels: European Commission DG Communications Networks, Content & Technology, October 2013), <http://ec.europa.eu/digital-agenda/en/news/quality-broadband-services-eu-samknows-study-internet-speeds>.
- ¹¹⁵ Akamai, "State of the Internet."
- ¹¹⁶ David Belson, *The State of the Internet: Fourth Quarter, 2013*, The State of the Internet (Akamai, Inc., Fourth Quarter 2013), http://www.akamai.com/dl/akamai/akamai-soti-q413.pdf?WT.mc_id=soti_Q413.
- ¹¹⁷ Ibid.
- ¹¹⁸ Netflix, "U. S.A ISP Speed Index Results."
- ¹¹⁹ Sascha Meinrath, "Audio of SOTN14: Debating Broadband Speeds in Akmerica: What Do the Numbers Say and Why Do They Matter?," *State of the Net*, January 18, 2014, <http://www.stateofthenet.org/media/sotn14-audio/>; Edward Wyatt, "U.S. Struggles to Keep Pace in Delivering Broadband Service," *New York Times*, December 30, 2013, sec. Technology; Crawford, *Captive Audience*.
- ¹²⁰ Tom Pica, "Verizon Wireless 4G LTE - LTE Advanced," *Verizon News Center*, July 16, 2013, <http://www.verizonwireless.com/news/article/2013/07/future-of-4G-LTE-nicola-palmer.html>.
- ¹²¹ Dan Jones, "Sprint Promises 180Mbit/s 'Peaks' in 2015," *Light Reading*, June 18, 2014, <http://www.lightreading.com/mobile/4g-lte/sprint-promises-180mbit-s-peaks-in-2015/d/d-id/709518>.
- ¹²² Phil Goldstein, "AT&T Lights up LTE Advanced Carrier Aggregation in Chicago, Other Markets," *FierceWireless*, March 7, 2014, <http://www.fiercewireless.com/story/att-lights-lte-advanced-carrier-aggregation-chicago-other-markets/2014-03-07>.
- ¹²³ Cisco Systems Inc., "Cisco VNI Resources," graphing tool, *VNI Forecast Widget*, (June 11, 2014), <http://www.ciscovni.com/forecast-widget/wizard.html>.
- ¹²⁴ OpenSignal, *The State of LTE February 2014*, February 2014, <http://opensignal.com/reports/state-of-lte-q1-2014/>.
- ¹²⁵ Ibid.
- ¹²⁶ HTTP Archive, "Trends."
- ¹²⁷ Akamai, "State of the Internet."
- ¹²⁸ HTTP Archive, "Average Bytes per Page by Content Type," web statistics, *HTTP Archive*, (May 29, 2014), <http://httparchive.org/index.php>.
- ¹²⁹ The target load time for web pages is one second, and Japan's speed is roughly 20 percent faster than U. S. speed.
- ¹³⁰ Web speed from Akamai, "State of the Internet." and page size from HTTP Archive, HTTP Archive, "Average Bytes per Page by Content Type."
- ¹³¹ Podelko, "How Response Times Impact Business?"
- ¹³² FCC Office of Engineering and Technology and Consumer and Governmental Affairs Bureau, *Measuring Broadband America - 2014*.
- ¹³³ Akamai, "State of the Internet."

¹³⁴ FCC's Office of Engineering and Technology and Consumer and Governmental Affairs Bureau, *2013 Measuring Broadband America: February Report*.

¹³⁵ SamKnows Limited, *Quality of Broadband Services in the EU March 2012* (Brussels: European Commission DG Communications Networks, Content & Technology, March 2012), <http://ec.europa.eu/digital-agenda/en/news/quality-broadband-services-eu-march-2012>.

¹³⁶ SamKnows Limited, *Quality of Broadband Services in the EU - SamKnows Study on Internet Speeds (second Report)*.

¹³⁷ SamKnows Limited, *Quality of Broadband Services in the EU March 2012*; SamKnows Limited, *Quality of Broadband Services in the EU - SamKnows Study on Internet Speeds (second Report)*.

¹³⁸ FCC's Office of Engineering and Technology and Consumer and Governmental Affairs Bureau, *Measuring Broadband America*, Measuring Broadband America (Washington, DC: Federal Communications Commission, August 2011),

http://transition.fcc.gov/cgb/measuringbroadbandreport/Measuring_U.S._-_Main_Report_Full.pdf; FCC's Office of Engineering and Technology and Consumer and

Governmental Affairs Bureau, *2012 Measuring Broadband America: July Report* (Washington, DC: Federal Communications Commission, July 2012),

<http://transition.fcc.gov/cgb/measuringbroadbandreport/2012/Measuring-Broadband-America.pdf>; FCC's Office of Engineering and Technology and Consumer and Governmental Affairs Bureau, *2013 Measuring Broadband America: February Report*.

¹³⁹ SamKnows Limited, *SAMKNOWS ANALYSIS OF ROGERS' BROADBAND PERFORMANCE IN MAY 2013* (Rogers Cable, June 28, 2013),

http://www.samknows.com/uploads/Rogers_Shortform_SamKnows_Broadband_Report_2013-06-28_Final.pdf.

¹⁴⁰ FCC Office of Engineering and Technology and Consumer and Governmental Affairs Bureau, *Measuring Broadband America - 2014*.

¹⁴¹ FCC's Office of Engineering and Technology and Consumer and Governmental Affairs Bureau, *2013 Measuring Broadband America: February Report*.

¹⁴² SamKnows Limited, *Quality of Broadband Services in the EU - SamKnows Study on Internet Speeds (second Report)*.

¹⁴³ Ofcom, *Infrastructure Report: 2013 Update* (Ofcom, October 24, 2013),

http://stakeholders.ofcom.org.uk/binaries/research/telecoms-research/infrastructure-report/IRU_2013.pdf.

¹⁴⁴ FCC's Office of Engineering and Technology and Consumer and Governmental Affairs Bureau, *2012 Measuring Broadband America: July Report*.

¹⁴⁵ OECD, "OECD Broadband Portal."

¹⁴⁶ Speeds from SamKnows Limited, *Quality of Broadband Services in the EU - SamKnows Study on Internet Speeds (second Report)*. Market shares from European Commission, *Digital Agenda Scoreboard 2013*, Commission Staff Working Document, Digital Agenda Scoreboard (Brussels: European Commission, June 12, 2013), https://ec.europa.eu/digital-agenda/sites/digital-agenda/files/DAE_percent20SCOREBOARD_percent202013_percent20-percent20SWD_percent202013_percent20217_percent20FINAL.pdf.

¹⁴⁷ FCC's Office of Engineering and Technology and Consumer and Governmental Affairs Bureau, *2012 Measuring Broadband America: July Report*.

¹⁴⁸ OECD, "OECD Broadband Portal."

¹⁴⁹ Speeds from SamKnows Limited, *Quality of Broadband Services in the EU - SamKnows Study on Internet Speeds (second Report)*. Market shares from European Commission, *Digital Agenda Scoreboard 2013*.

¹⁵⁰ FCC's Office of Engineering and Technology and Consumer and Governmental Affairs Bureau, *2012 Measuring Broadband America: July Report*.

¹⁵¹ World Bank, "Population (Total)."

-
- ¹⁵² Economic Commission for Europe Statistical Division, Trends in Europe and North America 2001 (UN Economic Commission for Europe, NY, 2001), p. 74. Aggregates compiled by NationMaster, "Countries Compared by People > Average Size of Households. International Statistics at NationMaster.com."
- ¹⁵³ OECD, "Criteria for the OECD Broadband Price Collections" (OECD Broadband Portal), accessed August 15, 2014, <http://www.oecd.org/sti/broadband/criteriafortheoecdbroadbandpricecollections.htm>.
- ¹⁵⁴ van Dijk Management Consultants, "Broadband Internet Access Cost" (European Commission, September 2012), http://ec.europa.eu/information_society/newsroom/cf/dae/document.cfm?doc_id=1156.
- ¹⁵⁵ Comcast, "Comcast Increases Internet Speeds for 13th Time in 12 Years," April 9, 2014, <http://corporate.comcast.com/news-information/news-feed/comcast-xfinity-internet-speed-increase>.
- ¹⁵⁶ Hibah Hussain et al., "The Cost of Connectivity 2013" (New America Foundation, October 28, 2013), http://oti.newamerica.net/publications/policy/the_cost_of_connectivity_2013.
- ¹⁵⁷ Ibid.
- ¹⁵⁸ Roslyn Layton and Michael Horney, *Innovation, Investment, and Competition in Broadband and the Impact on America's Digital Economy* (Arlington, VA: Mercatus Center, August 12, 2014), <http://mercatus.org/publication/innovation-investment-and-competition-broadband-and-impact-america-s-digital-economy>.
- ¹⁵⁹ Ibid.
- ¹⁶⁰ Yochai Benkler, *Next Generation Connectivity: A Review of Broadband Internet Transitions and Policy from Around the World* (The Berkman Center for Internet & Society at Harvard University, February 2010), http://cyber.law.harvard.edu/sites/cyber.law.harvard.edu/files/Berkman_Center_Broadband_Final_Report_15Feb2010.pdf; International Telecommunication Union, "Measuring the Information Society 2013," 2013, http://www.itu.int/en/ITU-D/Statistics/Documents/publications/mis2013/MIS2013_without_Annex_4.pdf.
- ¹⁶¹ van Dijk Management Consultants, "Broadband Internet Access Cost."
- ¹⁶² Point Topic, "Broadband Tariff Country Scorecard - Q1 2014," Data, *Point Topic*, (Q1 2014), <http://point-topic.com/free-analysis/broadband-tariff-country-scorecard-q1-2014/>.
- ¹⁶³ Infonetics Research, "Telecommunications Market Research: Telecom Market Analysis: Third Edition" (Infonetics Research, 2013).
- ¹⁶⁴ Campbell, "Global Wireless Matrix 4Q13."
- ¹⁶⁵ Point Topic, "Broadband Tariff Country Scorecard - Q1 2014."
- ¹⁶⁶ David Dean et al., "The Connected World: The Internet Economy in the G20" (The Boston Consulting Group, March 2012), <http://www.bcg.com/documents/file100409.pdf>.
- ¹⁶⁷ Hussain et al., "The Cost of Connectivity 2013"; Net Index from Ookla, "Global Value Index"; Andrew Burger, "Report: Average U.S. Broadband Prices Are Below World Average of \$76.61," Telecom News Analysis, *Telecompetitor*, (April 30, 2014), <http://www.telecompetitor.com/report-average-u-s-broadband-prices-are-below-world-average-of-76-61/>.
- ¹⁶⁸ J. S. Greenfield, "Are ISPs Gouging US Broadband Users?," blog, *CIMC Greenfield*, (February 18, 2014), <http://cimc-greenfield.com/2014/02/18/are-isps-gouging-us-broadband-users/>.
- ¹⁶⁹ Matthew Prince, "The Relative Cost of Bandwidth Around the World," *CloudFlare Blog*, August 26, 2014, <http://blog.cloudflare.com/the-relative-cost-of-bandwidth-around-the-world>.
- ¹⁷⁰ Vytautas Valancius et al., "How Many Tiers?: Pricing in the Internet Transit Market," *ACM SIGCOMM Computer Communication Review* 41, no. 4 (October 22, 2011): 194, doi:10.1145/2043164.2018459.

-
- ¹⁷¹ William B. Norton, "Definition of Internet Transit," *DrPeering International*, accessed July 29, 2014, <http://drpeering.net/core/ch2-Transit.html>.
- ¹⁷² Matthew Prince, "The Relative Cost of Bandwidth Around the World."
- ¹⁷³ *Ibid.*
- ¹⁷⁴ Campbell, "Global Wireless Matrix 4Q13."
- ¹⁷⁵ *Ibid.*
- ¹⁷⁶ *Ibid.*
- ¹⁷⁷ Morningstar, "Return on Invested Capital," *Investing Classroom*, 2010, <http://news.morningstar.com/classroom2/course.asp?docId=145095&page=9&CN=sample>.
- ¹⁷⁸ Viacom's Net Operating Profit after Taxes was negative in 2010-11, so we have ROIC for those years.
- ¹⁷⁹ Michael Cieply and Brooks Barnes, "Strong Profit Margin at Paramount Pictures Underlines a Hollywood Shift," *New York Times*, December 22, 2013, <http://www.nytimes.com/2013/12/23/business/media/strong-profit-margin-at-paramount-pictures-underlines-a-hollywood-shift.html?pagewanted=all&r=0>.
- ¹⁸⁰ Netflix financial report Q1 2014, "Segment Information".
- ¹⁸¹ ITU, "World Telecommunication/ICT Indicators Database 2014 (18th Edition)."
- ¹⁸² Yoo, *U.S. vs. European Broadband Deployment: What Do the Data Say?*; Roslyn Layton and Michael Horney, *Innovation, Investment, and Competition in Broadband and the Impact on America's Digital Economy*.
- ¹⁸³ ITU, "World Telecommunication/ICT Indicators Database 2014 (18th Edition)."
- ¹⁸⁴ Summary: *Zeran v. America Online*. (U.S Court of Appeals, 4th Circuit 1997).
- ¹⁸⁵ Rob Frieden, "Schizophrenia Among Carriers: How Common and Private Carriers Trade Places," *Mich. Telecom. Tech. L. Rev.* 19 (1997), <http://www.mttl.org/volthree/frieden.pdf>.
- ¹⁸⁶ Federal Communications Commission, *Deployment of Wireline Services Offering Advanced Telecommunications Services*, 47 CFR Parts 51, 64, and 68, 1998, <http://www.gpo.gov/fdsys/pkg/FR-1998-08-24/pdf/98-22597.pdf>.
- ¹⁸⁷ Federal Communications Commission, *Deployment of Wireline Services Offering Advanced Telecommunications Capability*, Federal Register (2001).
- ¹⁸⁸ Christopher K. Ridder, "AT&T Corp. v. City of Portland," *Berkeley Technology Law Journal* 15, no. 1 (n.d.): 20. Federal Communications Commission, *Internet Over Cable Declaratory Ruling: Declaratory Ruling and Notice of Proposed Rulemaking*, vol. GN Docket 00-185, CS Docket 02-52, 2002, https://apps.fcc.gov/edocs_public/attachmatch/FCC-02-77A1.pdf.
- ¹⁸⁹ "Supreme Court Rules in Brand X Case," *Tech Law Journal*, June 27, 2005, <http://www.techlawjournal.com/topstories/2005/20050627b.asp>; "FCC Classifies DSL as Information Service," *Tech Law Journal*, August 5, 2005, <http://www.techlawjournal.com/topstories/2005/20050805a.asp>.
- ¹⁹⁰ Robert McMillan, "The Father of Net Neutrality Returns to Do Battle With Comcast," *Wired Magazine*, June 25, 2014, <http://www.wired.com/2014/06/tim-wu/>.
- ¹⁹¹ Tim Wu, "Network Neutrality, Broadband Discrimination," *SSRN Electronic Journal*, 2003, doi:10.2139/ssrn.388863.
- ¹⁹² Crawford, *Captive Audience*. David Cay Johnston, *The Fine Print: How Big Companies Use "Plain English" and Other Tricks to Rob You Blind* (Penguin Group USA, 2012). Tim Wu, *The Master Switch: The Rise and Fall of Information Empires*, 1st ed. (New York: Alfred A. Knopf, 2010). Lawrence Lessig, *The Future of Ideas: The Fate of the Commons in a Connected World*, 1st ed. (New York: Random House, 2001). Many blogs echo this point of view: Peter Bright, "We Don't Need Net Neutrality; We Need Competition," Blog, *Ars Technica*, (June 26, 2014), <http://arstechnica.com/tech-policy/2014/06/we-dont-need-net-neutrality-we-need-competition/>. Nilay Patel, "The Internet Is Fucked," technology, *The Verge*, (February 25, 2014), <http://www.theverge.com/2014/2/25/5431382/the-internet-is-fucked>.

¹⁹³ Heather E. Hudson, "Broadband Policies for the North: A Comparative Analysis," November 2011, <https://scholarworks.alaska.edu/handle/11122/3964>.

¹⁹⁴ Ibid.

¹⁹⁵ Canada and Industry Canada, *Digital Canada 150*, 2014, http://epe.lac-bac.gc.ca/100/201/301/weekly_checklist/2014/internet/w14-14-U-E.html/collections/collection_2014/ic/lu64-48-2014-eng.pdf.

¹⁹⁶ The condition of local loop unbundling of fibers prohibits competitors from leasing a single strand of the access fiber from NTT-E/W; instead, they have to borrow the access fiber as a bundle of 8 strands. This condition reflects the network structure of FTTH, in which a backbone fiber is divided into 4 local main lines at the NTT's office and then further divided into 8 strands at the splitters that locate near user's premises. According to NTT-E/W, this is necessary to earn the fair return of network investment; on the other hand, competitors claim that this makes their market entry very difficult.

¹⁹⁷ MIC (2008) "Competition Review in the Telecommunications Business Field 2007" (in Japanese).

¹⁹⁸ MIC (2013) "Competition Review in the Telecommunications Business Field 2012" (in Japanese).

¹⁹⁹ Toshiya Jitsuzumi, June, 2014, personal correspondence.

²⁰⁰ Deutsche Telekom, "A Boost for Broadband Expansion: Federal Network Agency Approves Cooperation Model," *Deutsche Telekom*, June 4, 2012, <http://www.telekom.com/media/company/133040>.

²⁰¹ European Commission, "Regulation (EC) No 2887/2000 of the European Parliament and of the Council of 18 December 2000 on Unbundled Access to the Local Loop" (European Commission, December 18, 2000), <http://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:32000R2887>. European Commission, "Directive 2002/21/EC of the European Parliament and of the Council of 7 March 2002 on a Common Regulatory Framework for Electronic Communications Networks and Services (Framework Directive)" (European Commission, March 7, 2002), <http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=CELEX:32002L0021:EN:HTML>.

²⁰² Panayiota Tsatsou, "EU Regulations on Telecommunications: The Role of Subsidiarity and Mediation" (First Monday, January 3, 2011), <http://firstmonday.org/ojs/index.php/fm/rt/prtnerFriendly/3150/2745#11>.

²⁰³ Martin Cave, "Encouraging Infrastructure Competition via the Ladder of Investment," *Telecommunications Policy* 30, no. 3-4 (April 2006): 223-37. Thomas Hazlett and Coleman Bazelon, "Regulated Unbundling of Telecommunications Networks: A Stepping Stone to Facilities-Based Competition?" (TPRC, September 2005), <http://mason.gmu.edu/~thazlett/pubs/Stepping percent20Stone percent20TPRC.10.04.05 percent20.pdf>.

²⁰⁴ Steve Costello, "EC Kicks off 5G Effort," *Mobile World Live*, December 17, 2013, <http://www.mobileworldlive.com/ec-kicks-5g-effort>.

²⁰⁵ Ofcom, "Valuing Copper Access: Final Statement," August 18, 2005, <http://stakeholders.ofcom.org.uk/binaries/consultations/copper/statement/statement.pdf>.

²⁰⁶ Ofcom, "Review of the Wholesale Access Market," 2004, <http://stakeholders.ofcom.org.uk/binaries/consultations/rwlam/summary/rwlam.pdf>.

²⁰⁷ Ofcom, "Final Statements on the Strategic Review of Telecommunications," September 2005.

²⁰⁸ Brian Williamson and Sam Wood, "Mind the Gap: Why the MPF vs WLR+SMPF Price Differential Should Be Aligned with Costs Immediately" (Plum Consulting, February 2014), http://www.plumconsulting.co.uk/pdfs/Plum_Feb2014_mind_the_gap_MPF_vs_WLR_and_SMPF.pdf.

²⁰⁹ Ibid.

- ²¹⁰ James Hurley, "BT Faces Competition over Rural Broadband," *The Telegraph*, June 22, 2013, <http://www.telegraph.co.uk/finance/newsbysector/mediatechnologyandtelecoms/telecoms/10136770/BT-faces-competition-over-rural-broadband.html>; Christopher Williams, "Government Claims Economic Boost from £1.2bn BT Rural Broadband Subsidy," *The Telegraph*, November 14, 2013, <http://www.telegraph.co.uk/finance/newsbysector/mediatechnologyandtelecoms/telecoms/10448014/Government-claims-economic-boost-from-1.2bn-BT-rural-broadband-subsidy.html>.
- ²¹¹ Victoria Turk, "This Rural Community Is Building Its Own Gigabit Internet Network," *Motherboard*, May 7, 2014, <http://motherboard.vice.com/read/this-rural-community-is-building-its-own-gigabit-fibre-network>.
- ²¹² Ofcom, "Request from BT for Exemption from the Undertakings under the Enterprise Act 2002 for Certain High Bandwidth Services," July 25, 2012, http://stakeholders.ofcom.org.uk/binaries/consultations/above-1gb/summary/Above_1Gbt_Exemption.pdf; BT, "BT's Response to Ofcom's Consultation Document," September 30, 2013, <http://stakeholders.ofcom.org.uk/binaries/consultations/fixed-access-market-reviews/responses/BT.pdf>.
- ²¹³ IHS Inc., "Over Euro30 Billion Invested to Boost Western Europe's Next-Generation Broadband by 2017, IHS Technology Says" (Stockhouse, May 8, 2014), <http://www.stockhouse.com/news/press-releases/2014/05/08/over-euro30-billion-invested-to-boost-western-europe-s-next-generation>.
- ²¹⁴ Organisation for Economic Co-operation and Development, "DEVELOPMENTS IN CABLE BROADBAND NETWORKS" (Organisation for Economic Co-operation and Development, March 23, 2010), <http://www.oecd.org/internet/ieconomy/48459700.pdf>.
- ²¹⁵ Paul Weiss, "EC Threatens Legal Action against German Law Granting 'regulatory Holiday' to Deutsche Telekom," *Lexology*, March 2, 2007, <http://www.lexology.com/library/detail.aspx?g=4442572d-7f95-46cd-a311-170e30e3af55>.
- ²¹⁶ Kevin J. O'Brien, "Deutsche Telekom Is Ordered to Open Its Network to Rivals," *New York Times*, December 3, 2009, <http://www.nytimes.com/2009/12/04/technology/companies/04telekom.html>.
- ²¹⁷ Deutsche Telekom, "A Boost for Broadband Expansion: Federal Network Agency Approves Cooperation Model."
- ²¹⁸ Telegeography, "Telekom, Telefonica Intensify Fixed Network Cooperation," May 2, 2013, <http://www.telegeography.com/products/commupdate/articles/2013/05/02/telekom-telefonica-intensify-fixed-network-cooperation/>.
- ²¹⁹ Andrew Ross Sorkin, "Deutsche Telekom Is Expected To Sell 6 Cable TV Networks," *New York Times*, January 28, 2003, <http://www.nytimes.com/2003/01/28/business/deutsche-telekom-is-expected-to-sell-6-cable-tv-networks.html>. Hugh Eakin, "Deutsche Telekom Posts Europe's Biggest Loss," *The Age*, March 12, 2003, <http://www.theage.com.au/articles/2003/03/11/1047144967698.html>.
- ²²⁰ Margit A. Vanberg, "Competition in the German Broadband Access Market" (Centre for European Research, Mannheim, October 2002), <ftp://ftp.zew.de/pub/zew-docs/dp/dp0280.pdf>.
- ²²¹ BMWi, "The Federal Government's Broadband Strategy" (Federal Ministry of Economics and Technology, February 2009), <http://www.bmwi.de/English/Redaktion/Pdf/broadband-strategy,property=pdf,bereich=bmwi,sprache=en,rwb=true.pdf>.
- ²²² Ibid., page 21.
- ²²³ IHS Inc., "Over Euro30 Billion Invested to Boost Western Europe's Next-Generation Broadband by 2017, IHS Technology Says."

²²⁴ Richard Bennett, *Designed for Change: End-to-End Arguments, Internet Innovation, and the Net Neutrality Debate* (Washington, DC: Information Technology and Innovation Foundation, September 2009), <http://www.itif.org/index.php?id=294>.

²²⁵ Alain Baritault, "Sarkozy Digital Plan 2012 Ambitious, but Overshadowed by Financial Crisis," *Muni Wireless*, October 23, 2008, <http://www.muniwireless.com/2008/10/23/sarkozy-digital-plan-ambitious-but-overshadowed-by-financial-crisis/>.

²²⁶ Valéry Marchive, "France to Invest €20bn in High-Speed Broadband for the Entire Country," *ZDNet*, February 13, 2013, <http://www.zdnet.com/france-to-invest-20bn-in-high-speed-broadband-for-the-entire-country-7000011671/>. Mission Très Haut Débit, "Comprendre Le Plan France Très Haut Débit," *France Très Haut Débit*, 2014, <http://www.francethd.fr/comprendre-le-plan-france-tres-haut-debit/>.

²²⁷ Erin Coe, "E.U. Adopts New State Aid Regulations - Law360," *Law360*, December 12, 2006, <http://www.law360.com/articles/14908/e-u-adopts-new-state-aid-regulations>. European Commission, "State Aid: Commission Welcomes Court Judgment on French State Intervention in France Télécom," *EUROPA Press Releases*, March 19, 2013, http://europa.eu/rapid/press-release_MEMO-13-237_en.htm.

²²⁸ Leila Abboud and Gwenaëlle Barzic, "EU Opens Inquiry into Iliad Rates Concession," *Reuters*, April 13, 2012, <http://de.reuters.com/article/idUKL2E8FDD2H20120413>.

²²⁹ Gwenaëlle Barzic and Leila Abboud, "Orange Tops French Mobile Quality Review, Free Lags," *Reuters*, June 23, 2014, <http://www.reuters.com/article/2014/06/23/telecommunications-france-regulator-idUSL6N0P459920140623>.

²³⁰ Yoo, *U.S. vs. European Broadband Deployment: What Do the Data Say?*.

²³¹ Peter B. de Selding, "Manufacturers Seen as Likeliest Beneficiaries of French Satellite Broadband Funding," *SpaceNews*, February 6, 2014, <http://www.spacenews.com/article/financial-report/39407manufacturers-seen-as-likeliest-beneficiaries-of-french-satellite>.

²³² IHS Inc., "Over Euro30 Billion Invested to Boost Western Europe's Next-Generation Broadband by 2017, IHS Technology Says."

²³³ Paul Krugman, "What's The Matter With France?," blog, *The Conscience of a Liberal*, (August 27, 2014), http://krugman.blogs.nytimes.com/2014/08/27/whats-the-matter-with-france/?_php=true&_type=blogs&_r=0.

²³⁴ Jacint Jordana, "The Persistence of Telecommunications Policies in National States: Portugal and Spain in the European Arena," in *Governing Telecommunications and the New Information Society in Europe* (Cheltenham, UK: Edward Elgar, 2002), 86-109.

²³⁵ Panayiota Tsatsou, "EU Regulations on Telecommunications: The Role of Subsidiarity and Mediation."

²³⁶ Yoo, *U.S. vs. European Broadband Deployment: What Do the Data Say?*.

²³⁷ Agenda Digitale Italiana, "Progetto Strategico Banda Ultralarga," *Ministero Dello Sviluppo Economico*, 2012, http://www.sviluppoeconomico.gov.it/index.php?option=com_content&view=article&viewType=0&id=2019963&idmenu=2689&idarea1=1701&idarea2=0&idarea3=0&idarea4=0&andor=AND§ionid=0&andorcat=AND&partebassaType=0&idareaCalendario1=0&MvediT=1&showMenu=1&showCat=1&showArchiveNewsBotton=0&directionidUser=0.

²³⁸ IHS Inc., "Over Euro30 Billion Invested to Boost Western Europe's Next-Generation Broadband by 2017, IHS Technology Says."